



Providing food choices during a meal: Impact on food liking and food intake

Odile Parizel

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Providing food choices during a meal:

Impact on food liking and food intake

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Abstract

Out-of-home catering services frequently offer consumers the opportunity to choose their food from among different proposals and/or provide consumers with a variety of food. The present thesis aimed at investigating the effect of providing choice of equally-liked foods during a meal on food liking and food intake in healthy, normal-weight adults. The first part focused on two characteristics of a food product assortment (desserts) as modulator factors of the choice effect: (i) the degree of similarities between desserts and (ii) the level of pleasantness of desserts. Two independent behavioral studies using the same paradigm were carried out in adults ($n=80$ for each experiment) who participated in a choice and a no-choice session. Providing choice enhanced food liking no matter the degree of similarity between the desserts, but enhanced food intake only when products were sufficiently dissimilar. The choice effect on food liking and food intake was not modulated by the level of pleasantness of alternatives. The second part of the thesis assessed the impact of choice and/or variety on food liking and food intake. Fifty-nine adults participated in a 4-session study where they consumed vegetable dishes under the four following conditions: (i) being served one dish (no-choice/no-variety); (ii) being served three dishes (no-choice/variety); (iii) choosing one dish from among three (choice/no-variety); and (iv) choosing as many dishes as they wanted (choice/variety). Providing choice increased vegetable liking and vegetable intake, while offering a variety of vegetables only increased their liking. No synergy effect between choice and variety was observed on vegetable liking and vegetable intake (i.e. the effect in the choice/variety condition was not significantly higher than the effects in no-choice/variety and the choice/no-variety conditions). It may then be concluded that providing choice of food to adults increases food liking even when choice is made among similarly-liked foods. Regarding variety effect, however, its impact on food intake appears to be vulnerable to contextual factors, and especially, the degree of similarity between food options.

Keywords: choice, variety, food intake, food product assortment

Résumé

La restauration collective s'organise autour de modèle de type cafétéria ou buffet offrant aux consommateurs la possibilité de choisir le (ou les) aliments qu'ils souhaitent consommer. L'objectif de cette thèse était d'étudier les effets de donner l'opportunité à un individu de choisir ses aliments parmi des alternatives appréciées de manière équivalente au cours d'un repas sur le plaisir de manger et la prise alimentaire associée. L'ensemble des travaux a porté sur des adultes (en bonne santé et de poids normal) dont l'effet du choix a été évalué parmi des aliments d'appréciation équivalente. La première partie de cette thèse a évalué deux caractéristiques d'un assortiment de desserts pouvant moduler l'effet du choix : (i) le degré de similarité entre des desserts et (ii) le niveau d'appréciation initial des desserts. Deux études comportementales suivant le même paradigme expérimental ont été menées chez des adultes (n=80 dans chaque étude) assistant à une séance de choix et une séance de non-choix. Si les notes d'appréciation des desserts étaient plus élevées en situation de choix que de non-choix quel que soit le degré de similarité entre les aliments, un effet du choix sur la prise alimentaire n'a été observé que lorsque les produits étaient suffisamment dissimilaires. Le niveau d'appréciation initial des desserts n'a pas modulé l'effet du choix. La deuxième partie de cette thèse a étudié l'impact du choix et/ou de la variété sur l'appréciation de légumes et la prise alimentaire associée à travers une étude comportementale où chaque participant (n=59) a assisté chacune des conditions suivantes : (i) service d'une seule recette de légumes (non-choix/non-variété) ; (ii) service des trois recettes (non-choix/variété) ; (iii) choix d'une recette parmi trois (choix/non-variété) et (iv) choix d'autant de recettes souhaitées (choix/variété). Le choix et la variété augmentaient l'appréciation des légumes consommés mais seul un effet du choix a été observé sur la prise alimentaire. Aucun effet de synergie entre le choix et la variété n'a été observé sur l'appréciation des légumes ou la prise alimentaire. Ces travaux de thèse ont donc montré que donner à un adulte l'opportunité de choisir son aliment augmente l'appréciation de cet aliment, même si celui-ci porte sur des aliments appréciés de façon équivalente initialement. Cependant, l'effet du choix, comme de la variété, sur la prise alimentaire semblerait vulnérable à des facteurs de contexte et plus précisément le degré de similarité entre les aliments.

Mots clés : choix, variété, plaisir, prise alimentaire, assortiment

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List of abbreviations

BMI: Body Mass Index

DIDIT: Diet Impact and Determinants: Interactions and Transitions

GPA: Generalized Procrustes Analysis

LEX: Lexicographic decision model

SDT: Self-Determination Theory

SSS: Sensory-Specific Satiation

VAS: Visual Analogue Scale

WADD: Weighted additive model

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Parizel O. When foods are perceived as sufficiently different, food choice increases intake of the food chosen during a meal in humans. Neuroeconomics and Food Behaviours. November 20-21 2014, Grenoble, France.

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Parizel O, Labouré H, Marsset-Baglieri A, Fromentin G, Sulmont-Rossé C. Providing choice and/or variety: what impact on food liking and food intake? 11th Pangborn Sensory Science Symposium. August 23-27 2015, Gothenburg, Sweden.

PREFACE

Food choices in daily life

“Le mangeur moderne doit gérer non plus la pénurie mais la profusion” (Fischler, 1993)
(“The modern eater must deal not only with a lack but more likely with an abundance”)

One evening, I decided to have dinner with friends in a restaurant in Paris. Typing “restaurant Paris” on the internet, I found a website that proposed a list of almost 14,000 restaurants with quite a clear description of the ambiance, service, type of food and sometimes even the menus for each restaurant. Instead of investigating each restaurant one by one, I fortunately could refine my research by selecting some criteria (such as the cooking-style, price and localization) that would transform the initially long and exhausting task into a faster and easier investigation, and which would also better suit my expectations. The similar profusion of food products displayed in aisles of supermarkets has also raised great interest for the research community, especially regarding its impact on subsequent purchasing behavior.

Daily, we make a high number of choices regarding food: what to eat? When? Where? Wansink and Sobal (2007) reported that we make more than 200 food-related decisions per day. As the sociologist Claude Fischler already highlighted in 1993, profusion is becoming a contemporary issue that people are facing in their diet: people have to redouble their efforts to make choices among an overwhelming range of possibilities (Fischler, 1993). In western countries, we readily observe a trend in an increase in opportunities to make choices and, as the restaurant choice example illustrated, these choices tend to be increasingly complex. But making food choices do not only consist of choices made when selecting a restaurant or buying groceries in a store: it also occurs during a meal.

In France, 62 % of children (3-17 years old) and 74 % of adults (18-79 years old) still have their lunch at home. Among French individuals that have lunch out-of-home, the canteen remains the most typical place for children (63 %), while adults ate as much at the canteen (24 %) as in restaurants or fast food outlets (26 %) (Agence Française de sécurité sanitaire des aliments, 2009) . These figures do not only emphasize the diversity of locations frequented by people for lunch, but also highlight that people face a diversity of food presentation models which provide them with varying degrees of opportunities to make food choices.

At home as in some canteens (such as for children at primary school), choice mainly relies on the decision of the cook who prepares the meal. In out-of-home catering, such as in restaurants and canteens, people have the opportunity to decide the food they want to eat. In restaurants, people can select their food according to menus that vary in extensivity. According to the French meal model,

people can choose one starter, one main dish and one dessert from a list of alternatives. Canteens for schools, staff canteens and even some restaurants also propose self-service where people fill their tray with their own selection chosen from among a variety of starters, main dishes, cheeses and desserts. Lastly, we may find out-of-home catering most frequently in a buffet form, where people may to choose as many foods as they want with free second servings.

Providing choice has been identified as an important expectation of institutional catering consumers (CREDOC, 2014). In this sector, a tendency to change the traditional single meal into an offer that provides people a high variety of foods has been observed (CREDOC, 2014). Out-of-home catering pays particular attention to autonomy and freedom given to people who are able to compose their own meal. But, as Jean Pierre Poulain wrote, “*Avoir le choix est cependant un phénomène nouveau à l’échelle de l’histoire*” (“Having choice is a new and unprecedented phenomenon in history”) (Poulain, 2001). However, despite the intrinsic desire for people to have the opportunity to choose their own food within a meal, its impact on the quantities consumed has seldom been investigated.

Based on the evidence that modern out-of-home catering enables people to make more choices regarding their food within a meal, we do not know whether it impacts subsequent food behavior. Do people better enjoy their meal? Do they eat larger amounts?

What is choice?

Choice is frequently used in informal language, but how to define it? “This restaurant is very nice, you have made the right choice”, “There was so much choice today at the canteen” etc. are frequently heard expressions but have different meanings. In the first case, *choice* describes the result of a decision while in the second case, it refers to the number of food options from which people could select their meal. What exactly does *choice* mean? According to the Oxford Dictionary, choice is defined as:

- “an act of choosing between two or more possibilities”
- “the right or ability to choose”
- “a range of possibilities from which one or more may be chosen”
- “a thing or person which is chosen”

The first definition focuses on an *action* that involves a decision making process. The second emphasizes that choosing is an *opportunity* that provides some degree of freedom. In the third definition, choice is *the set of options*. The last definition refers to the *result* of the decision making process. According to the Oxford Dictionary, *to choose* is defined as “to pick out (someone or something) as being the best or most appropriate of two or more alternatives” or as “to decide on a course of action”. The first definition describes the process by which people identify the more relevant

option, while the second definition focuses on the fact that people have to deliberate with a final decision.

Despite *choice* being a commonly used word, previous definitions have used it to describe different things. Therefore, to provide better understanding during this thesis work and to avoid confusion, *food choice* is hereon defined as *the opportunity for an individual to select the food he or she wants to consume*. According to this definition, we consider *choice* as a freedom, provided to individuals, to pick out the food they want to eat by passing through a process of deliberation on the final food option.

Context of the thesis

The DIDIT meta-program (Diet Impact and Determinants: Interactions and Transitions) is a French research program initiated by INRA (Institut National de Recherche Agronomique). The meta-program has two main objectives: (1) to understand, model and predict the effects of the determinants of food behaviors, and (2) to establish relationships between food practices and health in order to evaluate the impact of interventions and provide recommendations for public health policies.

PleasIn is one of the DIDIT's projects, running from 2012 to 2015, that aims at providing better understanding of food choices. The objectives of the project are categorized in two main work-packages. The first work-package (WP1) aims at providing better understanding regarding the effects of providing choice on the pleasure of eating and food intake, while the second work-package (WP2) aims at deciphering neurobiological mechanisms involved in pleasure associated with food choice and food intake in humans. The research program DIDIT encourages a multi-disciplinary approach. PleasIn was a collaboration between four INRA laboratories: the UMR PNCA (Physiologie de la Nutrition et du Comportement Alimentaire) in Paris, the UMR CSGA (Centre de Sciences du Goût et de l'Alimentation) in Dijon, the UMR GENIAL (Ingénierie Procédés Aliments) in Massy and the UR QUAPA (Qualité des Produits Animaux) in Clermont-Ferrand. The present thesis is included in the WP1 of the PleasIn project and investigates the effects of providing food choices during a meal on pleasure of eating and the quantities consumed.

INTRODUCTION: LITERATURE REVIEW

The pleasure of eating a food and the quantities consumed are regulated by internal signals related to hunger sensations (Blundell et al., 2010), but are also influenced by external cues such as the context of the meal (Herman & Polivy, 2005). Social interaction (Pliner & Mann, 2004), the physical environment (Stroebele & De Castro, 2004) and even the presence of a variety of foods (B. J. Rolls, Rowe, et al., 1981) are examples of contextual factors that may influence food liking and/or food intake. This introduction provides an overview of the existing literature leading to the assumption that providing food choices during a meal impacts food liking and food intake. The first part of this literature review explores the mechanisms underlying food choices and presents behavioral studies investigating the effect of offering a choice of foods. The second part addresses factors that may modulate the impact of providing food choices on food liking and food intake. The third and last part of this introduction gives an overview of the effects of offering a variety of foods, since variety involves also making choices.

1. Providing food choices: mechanisms and effects

1.1. The decision-making process

1.1.1. Influences that governed food choices

When making choices, people do not only rely on individual cues but also on environmental cues. Three theoretical approaches have been developed by focusing at different levels of these two cues. The rationalist approach assumes that individuals make decisions that optimize benefits and minimize costs, while the structurist approach supposes that social institutions and environments provide norms and values that constrain or determine individual decisions. Finally, the constructionist approach takes into account both individual and collectivist perspectives by assuming that “individuals actively conceptualize and interactively interpret options in the process of deciding and reconsidering choices” (Sobal & Bisogni, 2009). Based on this last approach, Furst, Connors, Bisogni, Sobal, and Falk (1996) and afterwards Sobal and Bisogni (2009) developed a food choice process model, which provides a theoretical framework regarding decisions that are made for general food behaviors (buying food, cooking, eating, etc.) and in different contexts (at home, in restaurants, etc.). According to this model presented in **Figure 1**, food choices are governed by three major groups of factors (life course, influences and personal system) that interact with each other. The *life course* includes the past events and experiences as well as the social, cultural and physical environments which have affected and continue to affect an individual. *Life course* produces a set of *influences* organized into five categories

(ideals, personal factors, resources, social factors and present context). These influences guide an individual's *personal system*, which consists of the specific process used when making a food choice.

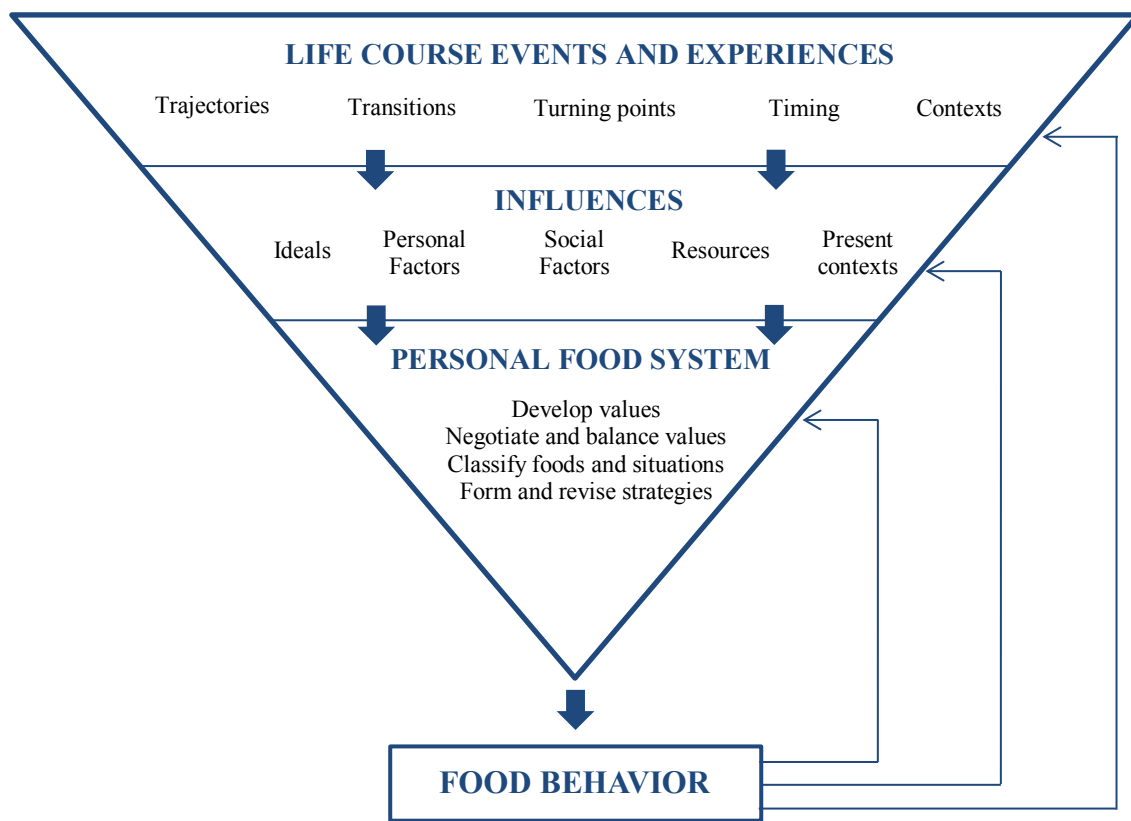


Figure 1. Food choice process model (adapted from Sobal and Bisogni, 2009)

1.1.2. Mechanisms of making food choices

In daily life, we face food choices where we have to select between several alternatives. The dynamic model suggested by Rangel (2013) and presented in **Figure 2** considers a four-stage process where individuals first identify their options, then compute the value among options to make a final choice. The third step consists of evaluating the final outcome once the choice is made. The dynamic characteristic of this model relies on the last stage, the “learning stage”; based on the final outcome evaluation of previous experiences, individuals memorize and update the value associated with the options.

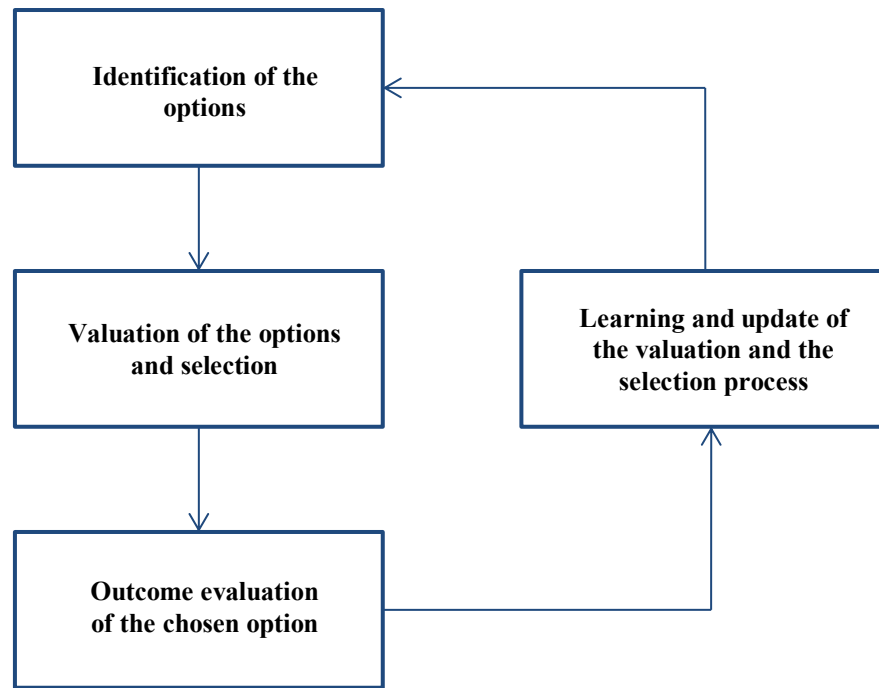


Figure 2. A four-stage decision making model (adapted from Rangel, 2013)

The process through which individuals select their food (step 2 in the model by Rangel (2013)) involves either a conscious mechanism of value negotiation or unconscious strategies based on habits (Scheibehenne, Miesler, & Todd, 2007; Sobal & Bisogni, 2009).

1.1.2.1. Decisions based on value negotiation

The process of value negotiation involves two steps where individuals first assign a value to each option and second, compare the different options (Zald, 2009).

In the first step of value assignation, individuals evaluate benefits (positive value) and losses (negative value) of each option by considering different criteria. Thus, Connors, Bisogni, Sobal and Devine (2001) suggested that people consider five primary food-related criteria (sensory perception, health, price, convenience and managing relationships) and for some people, additional values such as variety, symbolism, ethics, safety, quality and limiting waste. For example, eating an ice cream may appear beneficial regarding its sensory perception and convenience but is assigned a negative value regarding its price and the eater's health. The value assigned to each option is subjective and contextual: it depends on the intrinsic characteristics of the food alternatives as well as other factors such as the individual (e.g. physiological state, hunger) and the social context (Cardello, 1994). For instance, the value attributed to each alternative may depend on the presence of other options: the hedonic contrast posits that good stimuli reduce the pleasantness of less-good stimuli. For instance, diluted fruit juices were rated as less pleasant when subjects also received a good-tasting juice than when they did not

(Zellner, Allen, Henley, & Parker, 2006). Furthermore, the valuation process may also be based on expectations since usual food choices are made without having access to all information. For instance, in self-service canteens as in buffets, customers can see the multiple food options but do not know how they taste. The lack of overall information when making food choices supports the idea that people make choices based on *expected* value, which can be defined as $\text{expected value} = \text{probability} \times \text{estimated value}$ (Zald, 2009). Probability is the likelihood at which the estimated value would appear. The overall value construction, therefore, is a result of the value based on available information and expected value.

The second step of the process consists of comparing the values of food options to make a final decision (Sobal & Bisogni, 2009; Zald, 2009). With the aim of better understanding how individuals balance different options, Scheibehenne et al. (2007) compared the weighted additive mechanism (WADD) and the lexicographic decision heuristic model (LEX). The WADD model assumes that people assign a weight to each attribute according to its importance, and for each attribute, evaluate the value of the alternative. The overall value of the alternative is the addition of each attribute's value weighted by its importance. The LEX model is based on the assumption that people choose the alternative that has the highest value according to the most important attribute. Results showed that WADD and LEX models predicted 73 % and 72 % of the actual choices, respectively. While both models predicted results more accurately than those given by chance (i.e. 50 %), the study did not find any differences between these two models. The food choice process model (Sobal & Bisogni, 2009) also posits that individuals tend to use strategies to facilitate the trade-off process when comparing several food alternatives. People prioritize some values and categorize food and eating situations according to certain important values (Connors et al., 2001). Prioritizing values are necessary when values conflict. For example, choosing one alternative will satisfy one value while it may prevent fulfilling another value. Choosing an ice cream for a dessert will meet the taste value while it may prevent satisfaction of the healthiness value. A second strategy used by people to simplify food value negotiation is categorization. According to Connors et al. (2001), people organize foods into categories based on the main value (cost, taste, convenience, health, social relationship) that this food satisfies.

1.1.2.2. Heuristic based strategies

Since food-related decisions are numerous and often in a context where time is limited, people do not base their all decisions on complex and effortful trade-offs, but favor a more parsimonious and effortless process based on simple rules or heuristics (Scheibehenne et al., 2007; Sobal & Bisogni, 2009). People look to simplify food choice and then limit cognitive efforts by making them more automatic and habitual, and less conscious (Köster, 2003, 2009; Scheibehenne et al., 2007; Sobal & Bisogni, 2009; Wansink & Sobal, 2007). Wansink and Sobal (2007) showed that people make more

than 200 food-related decisions daily, but are not necessarily aware of all of these decisions. Based on work by Kahneman (2003), Köster also suggested that food choices are more likely governed by intuition than by rational considerations. Intuition refers to fast and implicit operations that are controlled by habits (as opposed to reasoning mechanisms that are guided by rational and conscious intentions). Implicit mechanisms such as memory, learning (for example acquired in the early childhood) and emotions are unconscious but strongly guide general food behavior and subsequent food choices. The idea that habits rely on a different mechanism than the valuation-based process has been discussed by Zald (2009). According to the author, habit-based mechanisms are initiated when products are familiar to the individual because they increase their confidence and therefore the expected value regarding the final outcome.

It could be then concluded that when facing food choices people use different strategies; the decision-making process should not be limited to one single model. Indeed, making food choices implies a diversity of contexts. Lack of time may be a contextual factor that prevents people from making complex decisions. In a supermarket, people choose products that would be consumed at several meals over the following days, while choosing in a self-service canteen is intended for immediate consumption at one meal. Choosing for future consumption suggests potential uncertainty about future preferences and a desire to keep options that enable a flexibility regarding this uncertainty: people are likely to select a subgroup of options that will maximize the likelihood of getting their preferred option in the future (Kahn & Lehmann, 1991). In a canteen or a buffet, people select their foods for immediate consumption without this future uncertainty (only if one product was the best and there is a risk that it would not be available in the future). Therefore, depending on the context and the repeatability of the decision, people favor either rational or heuristics-based decisions.

1.2. Effects of choice on behavior

The next section aims at providing a theoretical framework, showing that having the opportunity to make one's own choice influences subsequent behavior.

1.2.1. Self-Determination Theory: theoretical approach

A series of studies have demonstrated that providing choice may affect subsequent behavior. In 1975 Langer carried out an experiment based on lottery tickets. The tickets were sold to 50 people at \$1. Twenty-five people had the possibility to choose their ticket and 25 were assigned one ticket. Then participants were asked the price at which they would be ready to sell their ticket to another person. Participants having chosen their ticket requested a higher mean selling price (\$8.67) than participants who did not choose (\$1.96) (Ellen J. Langer, 1975). In 1978, Zuckerman, Porac, Lathin and Deci carried out a study based on puzzle-solving by children. Forty children chose 3 puzzles to solve among

6 as well as the time in which they expected to solve each one during a 30-min period. They were yoked to forty other children who were then assigned 3 puzzles and the time was determined by its yoked child in the other group. After the puzzle-solving task, children in both groups were free to do what they wanted during an 8-min free-choice period (including pursuing puzzle-solving). Zuckerman et al. (1978) pointed out that when having chosen their puzzle, children were more likely to pursue puzzle-solving during the free-choice period than children who had no choice. How can we explain these changes in behavior when provided choice?

Self-Determination Theory (SDT) is a macrotheory developed by Ryan and Deci based on human motivation. The theory posits that people are naturally inclined to pursue personal development and psychological growth. Nevertheless, the realization of this fundamental process of human nature depends on socio-environmental contexts (Deci & Ryan, 2002). In other words, some specific environments support this inherent process of self-development of human nature and on the contrary, other environments rather hinder it. As living organisms need nutrients for their physical development, the theory assumes that humans have three basic psychological needs that are necessary for their psychological growth and well-being:

- a need for *autonomy* refers to “being the perceived origin or source of one’s own behavior” (Deci & Ryan, 2002). A sense of autonomy enables people to “experience their behavior as an expression of the self” (Deci & Ryan, 2002);
- a need for *competence* is defined as “feeling effective in one’s ongoing interactions with the social environment and experiencing opportunities to exercise and express one’s capacities” (Deci & Ryan, 2002). The need for competence leads people to “seek challenges that are optimal for their capacities” (Deci & Ryan, 2002);
- a need for *relatedness* refers to “feeling connected to others, to caring for and being cared for by those others, to having a sense of belongingness” (Deci & Ryan, 2002).

As living organisms find nutrients in their environment, SDT posits that the satisfaction of these three psychological needs depend on the socio-environmental contexts. Social contexts that fulfill these needs will enhance intrinsic motivation, namely the desire to carry out an activity for self-gratification (as opposed to extrinsic motivation, the desire to carry out an activity for external rewards).

As mentioned above, the sense of autonomy is related to the internal vs. external origin of the behavior, defined as the *perceived locus of causality* in SDT. For external causation, the person will feel more subjected to environmental factors and will then perceive a lower sense of autonomy. For example, controlling events such as reward or punishment are perceived as an externalized source of causation. The person will more likely feel subjected to their social environment. In this way, extrinsic reward or punishments likely undermine intrinsic motivation. In contrast, when the causation of a behavior is perceived as personal, the individual feels a higher sense of autonomy that is expected to

increase intrinsic motivation. By choosing, people feel they are the origin of the situation (a perceived internal locus of causality) that increases the sense of autonomy and intrinsic motivation (Ryan & Deci, 2000). Choice may also affect a sense of competence. The previous section showed that when facing food choices people use different strategies. When making a food choice, people consider different options, even if the strategies used are varied (Köster, 2009; Scheibehenne et al., 2007). Considering the process of value negotiation (where individuals first assign a value to each option and second, compare the different options), choosing might be a complex task. When making a decision, people aim at choosing the more relevant option. In this sense, we may assume that the relevance of the chosen option in a complex choice situation might increase perceived competence and therefore intrinsic motivation.

Intrinsic motivation is evaluated by both behavioral and self-reported measures (Patall, Cooper, & Robinson, 2008). Behavioral measures consist of the degree of willingness to pursue the chosen task (e.g. additional time required to engage in a task). Self-reported measures are questionnaires addressing the interest, enjoyment or liking of the task, as well as reported willingness to engage in the task again. In some studies, intrinsic motivation has been evaluated by using both behavioral and self-reported measures. For example, in order to assess intrinsic motivation of children choosing puzzles, Reeve, Nix and Hamm (2003) used self-reported measures of interest (three items; e.g. “This puzzle is very interesting”), self-reported measures of enjoyment (three items; e.g. “The puzzle is fun”) with a 1-7 scale (anchors: *not at all true-very much true*) and by the additional time children spent in pursuing puzzle-solving (behavioral measure). It is then noteworthy that intrinsic motivation included both measures of satisfaction and of persistence.

We may go further with Langer and Zuckerman’s studies presented above. In Langer’s study concerning lottery tickets, even if the lottery outcomes resulted from chance rather than skills, we may assume that participants behaved as if they had control over the situation when they were provided choice. Langer suggested that this increase in the illusion of control leads to positive outcomes such as higher confidence and well-being. Regarding Zuckerman’s study (using a puzzle solving paradigm), we may assume that when providing a choice of which puzzles to solve, investigators also provided children the opportunity to better control the situation. Indeed, children in the choice group reported perceiving more control over the situation than children in the no-choice group. Therefore, providing choice enabled children to increase their intrinsic motivation, demonstrated by the additional time spent by children in the choice situation (Zuckerman et al., 1978).

Furthermore, providing choice not only increases intrinsic motivation but also leads to related outcomes. In their meta-analysis, Patall et al. (2008) showed that choice had a positive effects on effort, task performance, perceived competence and preference for challenge.

1.2.2. Field applications for autonomy-supportive methods

As choice may increase well-being, intrinsic motivation and other outcomes such as effort and performance, it has been suggested that it could be used as a strategy to improve behaviors such as learning performance in educational programs and increased involvement in medical treatment.

The effect of providing choice to children or students has been studied, in particular, as a teaching practice. Some studies used an educational computer program as a model to study the motivational benefits of providing choice (Cordova & Lepper, 1996; Iyengar & Lepper, 1999). Cordova and Lepper (1996) recruited 70 9-11 year-old children to participate in a 4-session study. During two sessions, children played a computer game designed to teach arithmetic. A mathematic evaluation was submitted to children before and after the intervention. Choice focused on game parameters (e.g. icon, name of the opponent). This study showed that even if choice was not based on the task itself, children in choice conditions reported higher levels of perceived competence, higher liking for the game and better mathematical learning. Reeve et al. (2003) used the same puzzle paradigm as Zuckerman et al. (1978) and investigated the impacts of “option choice” and “action choice”. “Option choice” consisted of deciding which puzzle to solve, while “action choice” focused both on the puzzle and the time required to solve it, as well as whether the child wanted to pursue it at the end of the allotted time or to switch to a new puzzle. Results showed that children having “action choice” reported more “internal locus” (measured by 3 items such as “I felt I was pursuing goals that were my own”) and displayed higher intrinsic motivations than children having “option actions” or no choice. Katz and Assor (2006) reviewed several studies and proposed that choice supports autonomy and motivation when it enables self-realization. In this situation, choice as part of a teaching method would be effective only when it reveals interest. Choice as a teaching method has been also tested in different ways, either as a choice of a task or a choice of the conditions in which it is performed.

Autonomy supportive health care provided by choice has also been studied as a medical strategy to improve health and well-being (Ng et al., 2012). **Figure 3** presents the model developed using SDT principles, assuming the impact of autonomy supportive methods in the medical field.

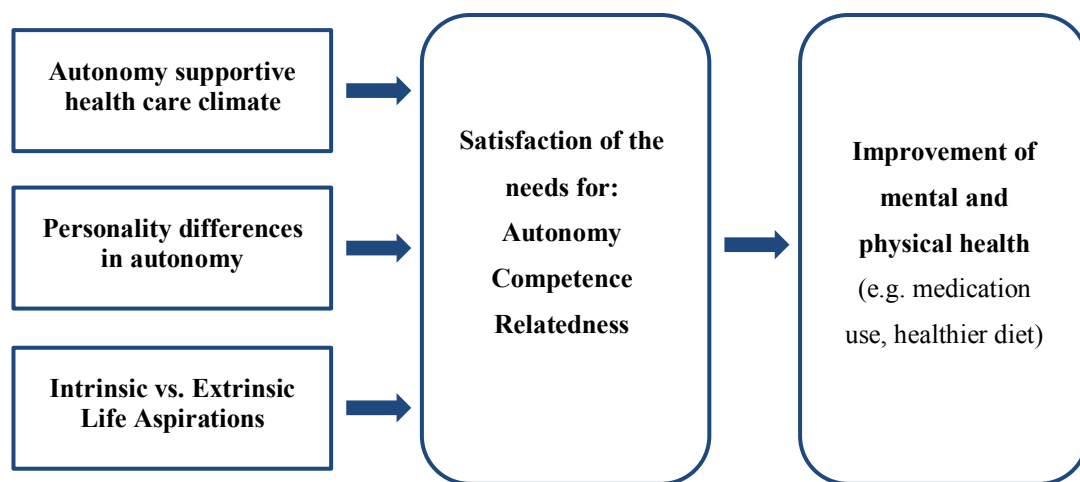


Figure 3. The Self-Determination Theory model of health change (adapted from Ryan, Patrick, Deci and Williams, 2008)

In 1976 E. J. Langer and Rodin carried out a study on residents of a nursing home. In a “Responsibility-induced group”, 47 residents were offered more responsibility, invited to participate in solving complaints about the nursing home, could make choices such as choosing a plant to care for by themselves, and deciding on the day they would watch films. In a comparison group, 44 residents were offered the same activities without any responsibility. Residents with responsibilities felt happier, had higher well-being, and were more active and involved in different activities than those in the comparison group. A study carried out by Williams et al. (2006) evaluated the benefits of an autonomy-supportive intervention on 1,006 adult smokers for tobacco cessation and cholesterol status improvement. The intervention was based on a 6-month period during which adults received information about smoking and cholesterol (e.g. risks, benefits of a cessation or status improvement, intervention programs), met a counselor who paid great attention to patients’ choices (concerning the decision of smoking cessation or change in diet, for example), encouraged them to be taken care of by medical professionals, supported patients’ initiatives, and elicited patients’ perspectives. Results showed that, compared to adults who only received information, adults following an autonomy-supportive intervention displayed higher motivation, higher perceived competence, better success in tobacco cessation even in the long-term, and had higher reduction of their LDL-cholesterol levels. In these examples, choice was not evaluated *per se* but was considered a major factor in autonomy-supportive interventions aimed at improving health and well-being.

1.3. Food liking and food intake

1.3.1. Food liking: definition

The appreciation of a food implies numerous terminologies (liking, palatability, pleasantness, pleasure and even acceptability) as well as a diversity of evaluation methodologies. **Table 1** displays examples of scales that have been used for hedonic evaluation of a food.

Table 1. Example of scales used for hedonic evaluation of a food

Scale	Description	Examples
Category scale	Fixed number of possible responses (described using words or figures)	9-point hedonic scale: 1: “dislike extremely”; 9: “like extremely” 10-point hedonic scale: 0: “I do not like it at all”; 10: “I like it very much”
Linear scale	Continuous scale anchored at both extremities	100-mm VAS “How pleasant is this food?” (“Not at all”-“Very”) 150-mm VAS anchored “Not palatable”-“Extremely palatable” 100-mm VAS anchored “Dislike extremely”-“ Like extremely”

Several authors have proposed definitions for some of these terms. For Blundell et al. (2010) liking is the “hedonic evaluation (pleasantness, appreciation) of tasting a particular food”. Palatability has been defined by Yeomans (1998) as a “hedonic evaluation of the food under particular circumstances”. The hedonic evaluation of a food questions whether it accounts for an invariant property of a food or whether it relies on a judgment of a food at the specific moment when it is eaten. For example, Yeomans and Symes (1999) highlighted that “palatability” had several meanings for consumers: for one group of consumers, palatability remained unchanged between the start and the end of a meal, while for a second group of consumers it decreased during the meal. Nevertheless, it appeared that pleasantness led to consensual understanding for consumers as it mainly decreased for all the consumers during the meal consumption.

Despite the debate about accurate definitions regarding these terms, we notice that all terms refer to the hedonic evaluation of the oro-sensory characteristics of a food. Since it is an evaluation made by an individual, we may assume that the pleasure would not only rely on the product itself but also on an interaction between individual and product. We may then conclude that the degree of pleasure when tasting and eating a food does not only include the inherent evaluation of the food but probably also the context in which the product is eaten.

1.3.2. Impact of food liking on food intake

Blundell et al. (2010) defined liking as the “hedonic evaluation (pleasantness, appreciation) of tasting a particular food”. The model, developed by Mela (2006) and presented in **Figure 4** illustrates that the degree to which an individual likes a food will influence the desire that he or she will feel to eat that food.

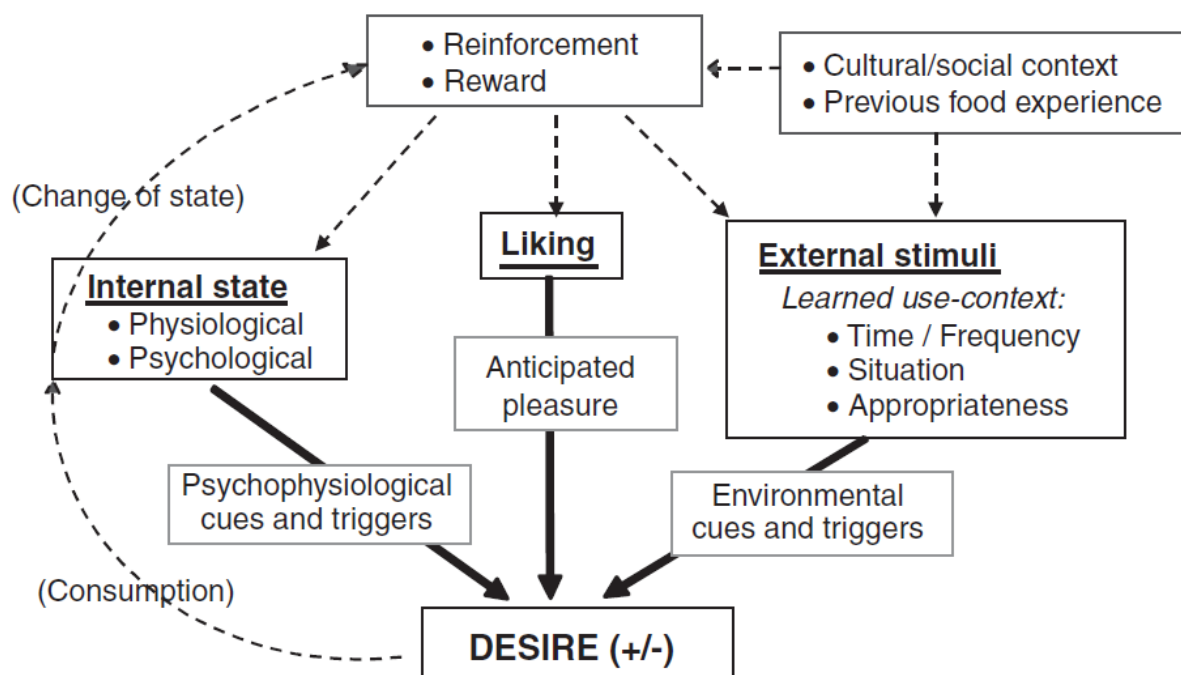


Figure 4. Scheme presenting the influences of liking, internal state and external stimuli on the desire to eat (Mela, 2006)

Several studies reported a positive relationship between food liking and food intake (Bolhuis et al., 2012; De Graaf et al., 1999; Sørensen et al., 2003; Yeomans, 1996). **Figure 5** presents results from Yeomans (1998) and illustrates that total intake of pasta was greater for the preferred condition of salt content than for the two others conditions (too low and too salty) rated as less pleasant. In 1999, De Graaf et al. compared the quantities consumed of soup with three different citric acid concentrations that led to three levels of palatability (highly palatable: 91; medium palatable: 43; non-palatable: 26). Results showed that participants ate medium-palatable soup and non-palatable soup 35 % and 60 % less than the highly palatable soup, respectively. In 2000, de Castro, Bellisle, Dalix and Pearcey investigated the impact of food palatability in real-life settings and showed that the higher overall palatability ratings of a meal were related to larger meal sizes. Nevertheless, they concluded that in real-life settings, food palatability only has a small impact on the quantities consumed since it accounted for only 2 % of the variance. One reason is that in a natural environment, people tend to select and consume food that they appreciate. According to the model presented by Mela (2006)

(Figure 4), liking is not the sole factor that may influence the desire to eat. Desire to eat, and most probably the quantities consumed are influenced by physiological and environmental cues. For example, we may appreciate a food without having any wish to eat it because we are not hungry. Figure 5 (B) especially illustrates that intake is influenced by both the level of pleasantness and the state of hunger (Yeomans, 1998).

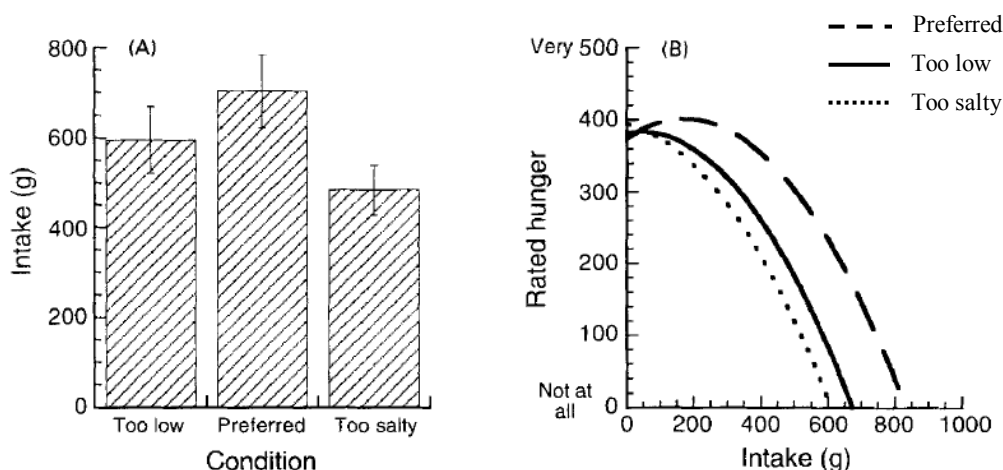


Figure 5. Total food intake (A) and quadratic functions relating rated hunger and food eaten (B) for men eating pasta with tomato sauce with too little salt (too low), with ideal amount of salt (preferred) and with too much salt (too salty) (Yeomans, 1998)

1.4. Effects of food choices on food behavior

The effect of socio-environmental factors assumed by SDT that might affect intrinsic motivation has also been investigated in the food behavior field. It is reasonable to expect that having a choice between food items would elicit greater food enjoyment and higher intrinsic motivation to eat (i.e. increase food intake) in the context of a meal.

1.4.1. Choice as a strategy to improve food behavior

A series of studies aimed at testing choice as part of potential strategies to improve children's acceptance of fruit and vegetables. In 1999, Hendy compared five teacher actions aimed at improving children's acceptance of fruit and vegetables: reward of a dessert, modeling (the adult tested new foods in front of the children), insisting that children try one bite, offering choice to determine whether the child wanted to test or not, and simple exposure of the new food without any intervention. This study based on 64 5 year-old children highlighted a positive effect of offering choice on children's new-food acceptance in that children tested new foods more often. In 2005, Hendy, Williams and Camise carried out an intervention investigating the effect of a school lunch program on children's fruit and vegetable acceptance. This program, named "Kids choice", used token reinforcement (which

consisted of punching holes of a card that could later be exchanged for a pizza), food choice and peer participation (as modeling), and was conducted with 188 elementary school children. Results showed an increase in fruit and vegetable acceptance during the intervention and also two weeks after. Nevertheless, seven months later, the acceptance had returned to the initial baseline, suggesting the importance of pursuing the program for a long-term period. A 2-year program, named Cafeteria Power Plus, was also put into place in 26 elementary schools, aiming at testing the effect of a multicomponent intervention. It included encouragement from the food service staff, special events in the cafeteria and the improvement of fruit and vegetable presentation by increasing choice offering (Perry et al., 2004). Zeinstra, Koelen, Kok, van der Laan and de Graaf (2010) conducted a survey study to identify parental strategies that may improve fruit and vegetable intake. The survey, completed by 242 4 to 12 year-old Dutch children and their parents showed a positive correlation between providing children with choice and their fruit and vegetable intake.

A series of long-term intervention studies conducted in real-life settings (nursing homes) have explored the effect of improving the mealtime experience of the elderly. These studies aimed at preventing nursing homes residents from malnutrition while increasing their well-being and their quality of life. Kremer, Derks, Nijenhuis, Boer and Gorselink (2012), Nijs, Graaf, Kok and Staveren, (2006) and Remsburg et al. (2001) used a multi-component approach that consisted of improving the general ambiance of the dining room, promoting social interaction, awareness of the nursing staff and organizing a food service that enabled people to choose and serve their own food. In their pilot study, Remsburg et al. (2001) compared a buffet-style dining program with a conventional meal service for the evening meal. The 3-month intervention study conducted with 40 residents did not reveal any differences, neither on residents' weight nor on their biochemical indicators of nutritional status. Nevertheless, the authors noticed that residents in the intervention group displayed high enjoyment regarding their evening meal. Nijs et al. (2006) carried out a 6-month intervention study on 178 residents of five Dutch nursing homes to evaluate the effect of a family-style diner. Results showed a difference between the intervention and the control group regarding the quality of life (measured by a questionnaire) and body weight. The authors also observed an increased effect of total energy intake for individuals consuming a family-style dinner. Kremer et al. (2012) conducted a pilot study on 68 residents of a Dutch nursing home to test a holistic approach of the meal and ambiance. They failed to observe any effect, neither on body weight nor on total energy intake. Nevertheless, authors reported an increased effect on intake of foods displayed as extras on table for food-service (vegetable, starch and sauce).

In 2007, King, Meiselman, Hottenstein, Work, & Cronk also investigated the overall effect of a restaurant setting where adult participants could especially chose the menu. They observed an increased effect on the liking of the eaten foods compared to tests carried out in their Central Location Test (laboratory or restaurant-like context).

These studies focused on meal contexts that were improved not only by providing choice, but also by improving social interaction and the quality of the dining room. Consequently, these studies did not set apart the impact of choice from the impact of other contextual variables.

1.4.2. Effects of providing choice on food liking and food intake

A series of studies have been more focused on the effect of providing choice on food liking and food intake and attempt to separate it from other contextual variables.

King et al. carried out several studies on American adults to investigate the effect of providing choice on food liking. In 2008, King, Meiselman and Henriques compared a “choice condition”, where adults could select to taste 3 of 6 salad dressings, to a “no-choice” condition where adults were served 3 salad dressings. They observed higher acceptability scores for the salad, the dressing and flavor in choice conditions than in no-choice conditions. In 2004, King, Weber, Meiselman, and Lv carried out a study to individually investigate contextual factors that may influence food behavior, such as social interaction, meal component, physical environment and the choice offering. Contrary to studies presented above, they isolated these different factors by running 6 different tests that each differed by one modified contextual factor. They observed a positive effect of choice on food liking in a restaurant context when participants chose one salad dressing from among two alternatives. However, this study did not reveal any impact of choice on the liking score for pizza or iced tea. More recently, Altintzoglou et al. (2015) observed a positive effect of choice on fish liking when children (11 to 12 years old) chose the fish they wanted to taste from among two alternatives. However, Zeinstra, Renes, Koelen, Kok and Graaf (2010) ran an experiment with children (Dutch, 4 to 6 years old) who dined in a restaurant with their parents and had the opportunity to choose from among similarly appreciated vegetables. The researchers failed to observe any impact of choice on vegetable liking.

To the best of our knowledge, only few studies have explored the impact of providing choice on food intake independent of other contextual factors, but provided mixed results. Zeinstra, Renes, et al. (2010) did not observe any impact of choice on vegetable intake. However, Rohlf's Domínguez et al. (2013) observed a 120 % increase in vegetable intake when children (Spanish, 4-6 years old) were allowed to choose the vegetable they wanted to consume for their school lunch from among two equally-liked alternatives, compared to a no-choice situation. Hadi and Block (2014) also showed that students who actively acquired chocolates were more likely to consume more than students that passively received the chocolates. Since the chocolate was the same in both conditions, this study supports the idea that even providing an individual an “illusion of choice” leads to a higher motivation to eat.

1.5. Conclusion of part 1

The Self-Determination Theory posits that providing choice is a way to enhance individual experience of competence and autonomy that results in an increase in intrinsic motivation and other outcomes such as satisfaction or performance. Providing choice has already been used as a strategy to improve behaviors such as learning performance in educational programs and higher involvement in medical treatment. It is reasonable to expect that having a choice between food items would elicit higher food liking and higher intrinsic motivation to eat (i.e. increased food intake) in the context of a meal (**Figure 6**).

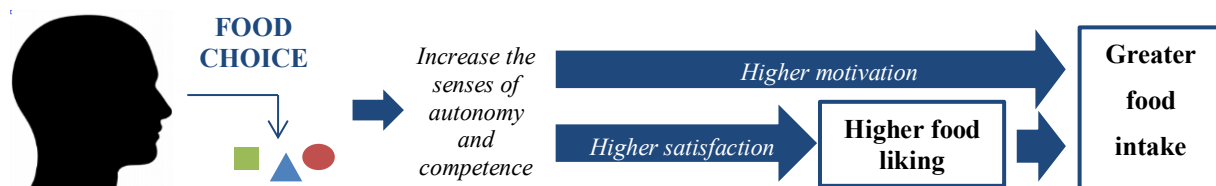


Figure 6. Hypotheses underlying the influence of providing food choice on food liking and food intake

Recent studies have investigated the impact of providing an individual the opportunity to choose their food on subsequent food behavior and have been carried out with different age groups (children, adults, elderly), in different contexts (in a laboratory versus a real-life situation) and with different food assortments (type of food, number of alternatives). Regarding this literature, it is not possible to clearly conclude the expected effect of providing choice on food liking and food intake. Some studies did not allow disentanglement of the impact of choice versus the impact of other contextual variables (Hendy et al., 2005; King et al., 2007; Kremer et al., 2012), such as social interaction or meal environment, which are likely to influence food intake and food choice (Stroebele & De Castro, 2004). Furthermore, providing choice also gives an individual the opportunity to select the most-preferred option. Therefore, without controlling the initial liking of the food alternatives offered, it cannot be concluded whether the increase in liking and intake when providing choice (vs. no-choice) is due to a “preference” effect or an effect of the choice *per se*. Thus far, only a few studies have investigated the effect of providing choice between equally-liked foods on food liking and/or food intake but did not lead to consensual results (Altintzoglou et al., 2015; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). The discrepancy between the results of Zeinstra, Renes, et al. (2010) and Rohlf's Domínguez et al. (2013) who carried out two experiments using the same protocol but in different contexts has led to the assumption that the choice effect is vulnerable to contextual factors.

2. Modulator factors of the choice effect

Previous studies and the Self-Determination Theory have shown that offering choice influences subsequent behavior. Nevertheless, some of the literature suggests that the choice effect is conditional. In 1995 Kühberger, Perner, Schulte and Leingruber (1995) failed to replicate the Langer effect (described above) and discussed the non-replicability based on an unknown combination of factors regarding protocols. In their paper, Katz and Assor (2006) also brought new insights concerning the debate about the benefits of providing choice as a teaching practice and identified motivating and non-motivating attributes for an effective choice. They especially pointed out the complexity of the set of options and the relevance of these options regarding personal interest and the value of the culture. More generally, Patall et al. (2008) carried out a meta-analysis on the effects of choice and identified a series of attributes that modulated the choice effect. Notably, they identified internal moderators relative to the individual, and external moderators related to the context, and more particularly, the characteristics of the set of products. This section presents some factors which have been shown to modulate the choice effect in all fields including those unrelated to food products.

2.1. Individual characteristics

2.1.1. Age

The modulator effect of age on the choice effect on intrinsic motivation or related outcomes has been rarely studied. In their meta-analysis, Patall et al. (2008) found that choice had a greater impact on intrinsic motivation in children than in adults. They suggested that children experience fewer opportunities to make choices than adults in their daily life, and this lack increases the choice effect once children have the opportunity. Altintzoglou et al. (2015) paid particular attention to the age of participants (11-12 years old) when investigating the impact of providing choice of two fishes on reported food liking. They stated that this age corresponds to the life stage during which children develop their ability to make choices for themselves (and particularly food choices). In 2004, Bereby-Meyer, Assor and Katz highlighted a difference in the choice strategies used by young children (8-9 years old) and older children (12-13 years old): when choice becomes more complex, young children were likely to use “less cognitive-demanding” strategies. Following this, it may then be assumed that young children facing a complex choice would perceive a lower sense of competence that might impact their intrinsic motivation.

Other studies also found a difference in the choice-making process between younger and older adults (Frey, Mata, & Hertwig, 2015; Mata, 2007; Mata, Josef, Samanez-Larkin, & Hertwig, 2011). It has been suggested that cognitive abilities decline with age, and that older adults are less likely to perform complex choices with an overload of information. From this perspective, we could expect that elderly

individuals with a decline in cognitive abilities are more likely to perceive the complexity of a choice, resulting in a non-optimal decision with a lower sense of perceived control that decreases their motivation (as described in the paradox of choice).

To the best of our knowledge, no studies have clearly investigated how age might influence the effect of providing choice on intrinsic motivation or related outcomes by comparing populations of different ages. Nevertheless, it may be suggested that children, teenagers, young adults and elderly individuals might behave differently when faced with food choices. Therefore, when studying the effect of providing choices on food liking and food intake, it is necessary to very carefully consider the age of the population concerned.

2.1.2. Culture

It has also been demonstrated that the choosers' culture may also be a modulator factor of the choice effect on intrinsic motivation (Patall et al., 2008). In 1999, Iyengar and Lepper notably showed that Anglo-American and Asian-American children displayed different intrinsic motivation and performance according to the person who made the choice. In one study, 7 to 9-year-old children had to complete anagrams in an initial 6-min period and were then free to do what they wanted in a second 6-min period (including pursuing the anagrams task if they wished). The choice of anagrams was either made by the child him or herself, by the investigator, or by his or her mother. Anglo-American children performed better (e.g. had a higher number of correctly solved anagrams) and displayed higher intrinsic motivation (e.g. spent more time continuing to solve anagrams in the second session) when they had chosen the anagram by themselves (personal choice), while Asian-American children performed better and displayed higher intrinsic motivation when the choice was made by their mother. Iyengar and Lepper ran a second similar study on 9 to 11 year-old children who completed computer games to learn mathematics. Results showed that Anglo-American children showed higher intrinsic motivation when they had chosen the game by themselves (e.g. they expressed higher liking to pursue the game, were more engaged in the game by attempting a higher number of games, and expressed higher liking for mathematics), while Asian-American children displayed higher intrinsic motivation when the choice was made by a classmate. Anglo-American children also learned mathematics better when they had chosen the educational computer game, while Asian-American children learned better when the choice was made by a classmate.

In fact, American and Asian cultures display different conceptions of the self (Markus & Kitayama, 1991). While American culture emphasizes an individualistic model of the self, Asian culture corresponds to a collectivistic model with a higher sense of relatedness and belongingness. Hence, personal choices enable Americans to express their own preference and to assert their own autonomy, central to their self-identity model. In contrast, Asians with a higher sense of interdependence,

community and belongingness would be more likely to adhere to choice made by a trusted authority (e.g. their mother) or a peer (e.g. a classmate).

2.1.3. Psychological traits

Psychological traits are internal factors (personality traits and behavioral characteristics) that define an individual. Regarding choice-making, some of these personal traits, such as the process used by individuals when making a decision or the degree to which people want to control their life, may modulate the satisfaction of the three psychological needs that impact the intrinsic motivation and related behaviors.

When making a choice, people may be characterized according to their tendency of using a maximizing or a satisfying strategy (Schwartz et al., 2002). Maximizers are people who make choices by looking for the best option, while satisficers are more likely to seek what is “good enough”. By exploring all alternatives and paying a lot of attention to social feedback, maximizers invest time and effort during the decision-making process (Iyengar, Wells, & Schwartz, 2006). In contrast, satisficers are less inclined to engage in social comparisons, and tend to evaluate options until one reaches a threshold of acceptability. Iyengar et al. (2006) suggested that maximizers also have higher expectations than satisficers. Therefore, looking for the “best option” relies on a difficult, complex and exhausting process whereas maximizers face cognitive limitations that prevent them from making the expected best choice. Despite maximizers having higher expectations regarding the final decision, they reported more negative affects regarding the decision process and the final outcome (Iyengar et al., 2006; Schwartz et al., 2002). We may then assume that maximizers are more likely to feel a loss of perceived control when making complex choices that, according to the SDT, leads to a decrease in intrinsic motivation and related outcomes.

The desire for control is a stable psychological trait that characterizes the individual tendency to control life events. It has been shown that the desire for control is related to the satisfaction of psychological needs and intrinsic motivation. It has also been reported that individuals with a higher desire for control tendency display higher motivation to make their own decisions (Burger, 1990).

2.2. Modulators related to product assortment

2.2.1. Assortment structure

Based on the evidence that supermarket offerings have considerably increased in recent decades in Western countries, a series of studies have evaluated the impact of providing choice depending on the number of the options offered. According to Self-Determination Theory, it could be assumed that increasing the provision of choices would positively impact intrinsic motivation, well-being and other

outcomes such as satisfaction. Reutskaja and Hogarth (2009) carried out an experiment on 120 students who were asked to choose one gift box among an assortment of 5, 10, 15 or 30 options that varied in color and/or shape. Participants reported their satisfaction for the chosen option (outcome satisfaction) and for the decision-making process (process satisfaction). Outcomes showed higher option satisfaction and process satisfaction when provided a medium-sized assortment (10 options) compared to low-sized assortment (5 options). The authors also reported a decrease in both satisfactions when the assortment became extensive (30 options), and suggested that satisfaction from choice varied as a function of a number of options. Similarly, Shah and Wolford (2007) reported that people were more likely to buy a pen when provided middle-sized assortments (from 8 to 14 options) than low-sized assortments (from 2 to 6 options) and high-sized assortments (from 16 to 20 options). Both studies supported the hypothesis that satisfaction and intrinsic motivation varied according to an inverted U-shape function of the number of alternatives. Further studies have investigated the effect of providing choice among extensive assortments. Iyengar and Lepper (2000) ran a series of three experiments that compared choices made among limited-sized assortments and choices made among extensive-sized assortments. They observed that participants were less likely to purchase a jam when they were offered a choice from among 24 flavors of jam than when they were offered a choice from among 6 flavors of jam in a grocery store.

These negative consequences of extensive assortments on satisfaction and motivation to make a choice have been described by a number of theories such as the “choice overload” (Iyengar & Lepper, 2000), the “too-much-choice effect” (Scheibehenne, Greifeneder, & Todd, 2009), the “tyranny of choice” (Schwartz, 2004) or the “excessive-choice effect” (Arunachalam, Henneberry, Lusk, & Norwood, 2009). Several hypotheses have been proposed to explain this phenomenon. It may be assumed that making a decision from a large assortment increases time and effort required when processing the decision, due to an overload of information when comparing the alternatives. When providing more options, people may also have a greater sense of finding the more appropriate option(s), which tends to increase their expectations regarding the final decision. Schwartz (2004) also suggested that the more people invest in making a choice, the greater are the expectations of the final decision. Nevertheless, it may be assumed that extensive assortments prevent from making an optimal choice: when providing too many alternatives, the comparison between all alternatives becomes an overly complex task. The author posited that people feel regret when making a decision that is not the best, most probably enhanced by their high expectations when facing large assortments. According to Reutskaja and Hogarth (2009), the satisfaction of a choice result from a difference between costs and benefits when making the decision. Indeed, when increasing the number of options, the various costs (i.e. costs due to the time spent to make a decision, costs related to the cognitive efforts and also costs of anxiety due to the uncertainty of making the right decision) would increase. Nevertheless, benefits due to the likelihood of finding a more appropriate option and to the higher perception of autonomy and freedom

tend to increase to a lesser extent. Hence, satisfaction would follow an inverted U-shape function of the number of alternatives (**Figure 7**).

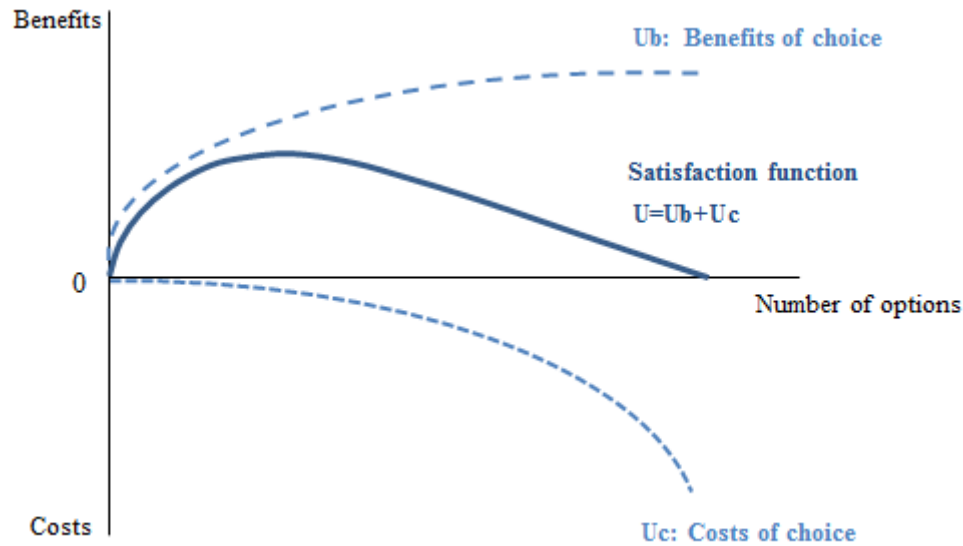


Figure 7. Satisfaction (U) resulting from the costs (U_c) and the benefits (U_b) of the choice as a function of the number of alternatives (adapted from Reutskaja and Hogarth, 2009)

Nevertheless, the “too-much choice” effect due to high number of options has been questioned. In 2010, Scheibehenne, Greifeneder and Todd performed a meta-analysis on 63 experiments comparing the impact of small vs. large assortments on either self-reported satisfaction with the final chosen option or on whether an active choice was made. The meta-analysis revealed a mean effect of the assortment size of zero, but with considerable variance between studies. In fact, the authors hypothesized that the relationship between the assortment size and the impact of choice on intrinsic motivation and satisfaction should be modulated by some factors such as the ease with which alternatives can be categorized, the degree of similarity between the alternatives and/or the number of attributes that differentiate the alternatives. For instance, Greifeneder, Scheibehenne and Kleber (2010) observed that increasing the number of MP3-players (from 6 to 30) led to a decrease in satisfaction only when the MP3-players differed in a high number of attributes (9 vs. 4). These authors then suggested that both the number of options and the number of attributes that differentiate alternatives tend to modulate the choice complexity.

Indeed, it has been more generally suggested that the amount of information may affect decision processing and the quality of the final decision. In 2004, Lurie proposed a structural approach to information and posited that not only the number of alternatives, but also the number of attributes that differentiate alternatives, the number of attribute levels and the distribution of these levels (i.e.

uniform vs. non uniform) tend to increase the amount of information. They also showed that the amount of information affects decision processing and the quality of the final decision. Although their studies did not evaluate the impact of information overload on overall satisfaction and motivation, we may assume that the difficulty of processing, and a decrease in the decision quality, may influence it. Fasolo, McClelland and Todd (2007) suggested that providing less attribute information would not impair the final choice and may even prevent from an information overload.

Studies from Mogilner, Rudnick and Iyengar (2008) have also demonstrated that the organization of options into categories would influence the choice effect. The authors carried out an experiment where 50 different coffees were presented on a menu with or without category grouping. The results showed that people unfamiliar with these coffees displayed higher satisfaction with their chosen coffee when they were presented with categorized coffees than non-categorized coffees.

2.2.2. Nature of the assortment

In 2005, Chernev carried out experiments on the complementarity of attributes that differentiate the alternatives. Complementarity attributes are those having additive utilities, while non-complementarity attributes are characterized by non-additive utilities. In his first experiment, Chernev (2005) compared assortments of MP3-players that differed in varied options (e.g. complimentary attributes such as being user-friendly design, having clear sound) and assortments of MP3-players that differed in color (non-complementary attributes). They showed that individuals were more likely to defer their choice when facing complementary assortments than non-complementary assortments. The author suggested that with non-complementary assortments people tended to consider a high number of factors when evaluating the options. Similarly, further research has been carried out on the alignability of the options (Markman & Medin, 1995; Zhang & Fitzsimons, 1999). Alignable attributes are those that are related and that may be compared, while non-alignable attributes are unrelated and may then not be compared. For example, in a comparison between an orange juice and a soda, the fact that orange juice contains lower calories than soda contains is an alignable difference. In contrast, the fact that orange juices contain fruits while sodas do not is a non-alignable difference. Zhang & Fitzsimons (1999) found an increase in satisfaction with the choice process when alternatives differed in alignable attributes, compared to alternatives that differed in non-alignable attributes. They also showed that people choosing between options that differ in alignable attributes perceived the comparison between options to be easier, and also perceived a greater amount of relevant information to make their choice.

2.3. Conclusion of part 2

This second part of the literature overview aimed at providing some insights regarding the modulator effects of providing choice on subsequent behavior, such as satisfaction and motivation. This section

highlighted that some factors, which rely on the chooser's characteristics or on external factors such as assortment, may modulate the choice effect (**Figure 8**). This part of the review dealt with internal and external factors separately, but it would be more accurate to consider both at the same time as they do interact simultaneously. For example, the preference for large assortments (external modulators) may differ depending on the individuals' culture (individual characteristics). For instance, Scheibehenne et al. (2009) showed that American individuals prefer larger assortments (of charity organizations) than do German individuals. It may be also assumed that maximizer individuals would be less comfortable when facing extensive assortments than satisficer individuals. Chernev (2012) also showed that perceived variety depends on the strategy used by the individual, and when facing a choice. As perception relies on an interaction of an individual with their environment, including the assortment he or she encounters, it is important to take into account the relationship between the individual and his or her environment.

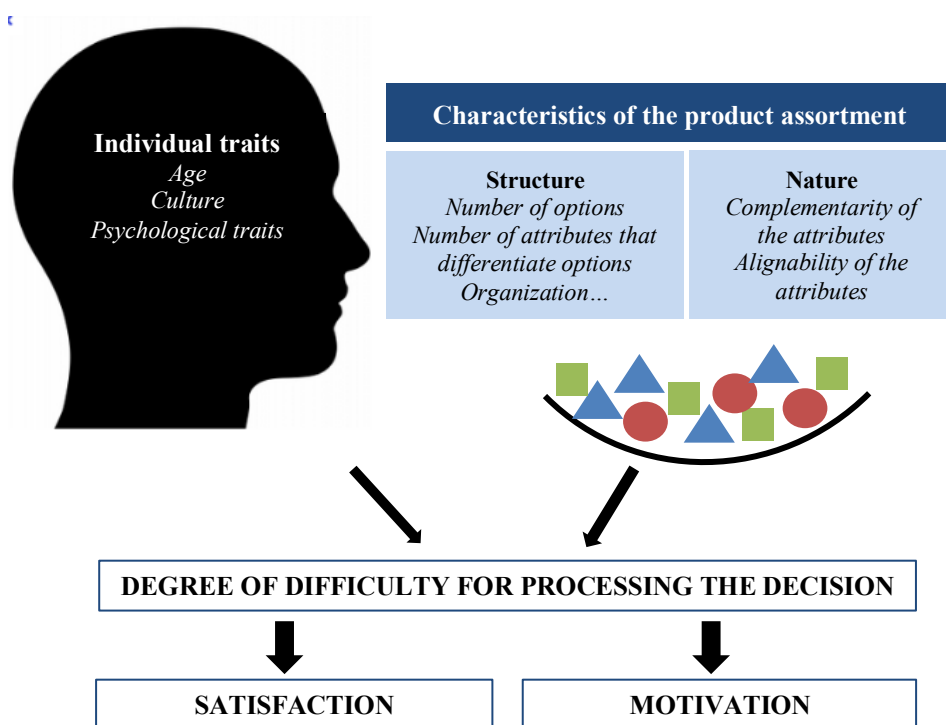


Figure 8. Effects of the modulator factors related to the individual and the characteristics of the product assortment that influence the satisfaction and motivation when choosing

Furthermore, the effects of modulators have been mainly investigated in the economic research field, and were not only based on food products but also on a diversity of goods (e.g. MP3-players, magazines) and activities (e.g. giving to charity organizations). Before making generalizations about the factors that may influence the choice effect, we suggest that the object of choice should first be taken into account. Indeed, choosing a house to purchase and choosing a food to eat for lunch would not require the same engagement in the task as their outcomes would have different impacts. We may

then suggest that the decision relies on different decision-making processes and would probably have a different impact on the final decision. Some modulator factors do exist but we must pay great attention to their generalization on food choices.

3. Choice and Variety

We previously analyzed the choice effect on food behavior as the effect of choosing one food. In real-life situations, individuals may also have the opportunity to select several food items, such as several side dishes for the main dish in a self-service canteen, or several hors d'oeuvres in a buffet. These situations offer one not only the opportunity to choose their food, but also the opportunity to eat a variety of foods. Indeed, choice situations are mainly associated with the offer of a variety of food.

3.1. Definitions of choice and variety

As we already mentioned in the preface, the definition of choice elicits different meanings. Choice may be considered as an action (“an act of choosing between two or more possibilities”(Oxford Dictionary)), may refer to the characteristics of an assortment (“a range of possibilities from which one or more may be chosen”) or a result (“a thing or person which is chosen” (Oxford Dictionary)). Considering the second definition of choice by saying that “we have many choices”, would closely refer to the variety of the assortment we encounter. According to this definition, the definitions of choice and variety are ambiguous.

As this thesis work focuses on the impact of making a choice on food behavior, we considered choice most likely to be the action of making a decision. In the preface, we already defined choice as the opportunity for an individual to select the food he or she wants to consume. This definition therefore takes into account the psychological effects (such as feeling more autonomy) of giving an individual the opportunity to deliberate on the final decision. We considered variety as a characteristic of a food presentation. As follows, we defined variety as the presentation of multiple foods with different sensory characteristics that a person is allowed to eat.

3.2. Choice versus variety in the literature

This section aims at presenting an overview of the literature regarding studies investigating the impact of choice and variety on food liking and food intake. It will especially focus on paradigms carried out how both are involved in experiments.

3.2.1. Framework of the literature review

In humans, numerous studies have already investigated the effect of providing a variety of foods on food intake (named the "variety effect") in different situations (Kramer, Leshner, & Meiselman, 2001; Meengs, Roe, & Rolls, 2012; B. J. Rolls, Rowe, et al., 1981; Spiegel & Stellar, 1990; Zandstra, de Graaf, & van Trijp, 2000). It is important to distinguish situations that have certain conditions such as temporality. The variety effect has been considered in a context of one meal ("within-meal variety"), across several meals ("across-meal variety") and over a longer period such as a month or even years ("dietary variety") (Meiselman, deGraaf, & Leshner, 2000; Remick, Polivy, & Pliner, 2009). This thesis work investigated the impact of providing choice during a meal: we focused on the variety offered in the same context (i.e. "within-meal variety"). Other studies have also investigated choices made among a variety of food items for future consumption, such as simultaneous choices for sequential consumption (Kramer et al., 2001; Wu & Kao, 2011). This may be analogous to a purchasing action made for multiple-meal planning, but involved other factors such as goal orientation strategies to consider the future. We also did not take into account protocols which aimed at an improved understanding of the variety effect mechanisms and introduced intermediate measurements (such as intermediate measure of pleasantness) during the eating period (Brondel et al., 2009).

In this literature review, we will only focus on human studies that investigated food variety during a meal, and only those looking at immediate consumption (i.e. no long-term variety and no purchasing action). Regarding choice, we analyzed studies that investigated the choice effect without confounding factors of context, also within the timeframe of a meal for immediate consumption.

3.2.2. Results from the literature review

The aim of this part of the literature review was to investigate the different paradigms used when studying variety and choice. It is not systematic, but nevertheless provides a complete picture of the protocols carried out.

The overview of the paradigms used when studying the variety effect and choice effects on food liking and food intake is displayed in **Table 2**. This table summarizes information about the population studied (sex and age group), the kind of foods and a brief description of the conditions (How products were served in the test and control conditions?). For each study, we investigated how variety and choice, as defined above, were involved whether the announced purpose of the study dealt with variety or choice. For variety, we specified whether it was sequential (when foods were presented one by one) or simultaneous (when foods were presented all together). When choice was involved, we specified whether it was explicit (e.g. the investigator asked the participant to select the food he/she wanted to eat) or implicit (e.g. the investigator did not ask the participant to select the food he/she wanted to eat). While these studies evaluated the impact of variety or choice on food liking or/and food intake, we

may assume that an increase in food liking and/or food intake might be because people had the opportunity to eat their favorite food in variety and choice conditions. Therefore, we found it relevant to look into the hedonic control (i.e. how did these studies take into account the possible effect of preference?).

3.2.2.1. General results

Firstly, the effect of providing variety within a meal has been investigated for more than 30 years in humans, while the effect of providing choice has been the subject of very recent studies. Among those investigated, most studies on the variety effect were carried out on adults, using a within-subject design, while studies on the choice effect were carried out on children according to a between-subject design. Studies investigating sequential variety used simple products such as hors d'oeuvres, yoghurt and sandwiches, which refer to food usually proposed during a buffet; only one study used components of a meal (B. J. Rolls, Van Duijvenvoorde, & Rolls, 1984). Nevertheless, studies investigating simultaneous variety and choice typically based their protocols on a standard meal with vegetables as the tested product.

3.2.2.2. Variety and choice: two factors embedded

We have already pointed out that variety includes two possible food presentations: a sequential presentation where products are presented one after the other over several courses; and a simultaneous presentation where the all options are offered during the same course. Pliner, Polivy, Herman and Zakalusny (1980) mentioned that sequential presentation of foods may refer to a French meal model with several courses, while a simultaneous presentation would likely refers to a buffet. In all studies cited, products presented in sequential variety were assigned to participants who did not choose their products. Nevertheless, in simultaneous variety, people were allowed to select the foods they wanted to eat among all that were presented; they had the opportunity to choose even if people were not explicitly conscious of the fact. Considering this, we may assume that simultaneous variety also involved implicit choice.

In four studies detailed in **Table 2**, the authors compared no-choice sessions where participants were assigned one food, to a choice session where participants had to choose one of two foods (Altintzoglou et al., 2015; King et al., 2004; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Zeinstra, Renes, et al. (2010) and Rohlf's Domínguez et al. (2013) also carried out a third session where participants were provided a plate with two vegetables. This situation is similar to simultaneous variety situations studied in variety studies described above: choice is implicit. In this session, the authors did not only evaluate the choice effect but also the variety effect. Rohlf's Dominguez et al. (2013) highlighted a temporal characterization of this kind of choice. In a simultaneous variety, choice

is “continuous”: individuals are served with several foods and then can make choices each time they pick up food from their plate to eat.

3.2.2.3. Variety and choice: specific effects or preference effect?

In variety situations, we must consider the confounding effect of preference. In sequential variety, people receive different foods at different courses and can, during one course, receive their favorite food. That would not necessarily be the case in the no-variety scenario where people are only assigned one food throughout all the courses. Also when providing several foods simultaneously, people can choose to eat their preferred food to the detriment of their less-preferred food. Then, is the effect on food intake due to the variety *per se* or to the opportunity to eat or select their preferred foods? Several articles have already addressed this issue (Pliner et al., 1980; B. J. Rolls, Rowe, et al., 1981; Spiegel & Stellar, 1990), using different strategies to test the liking of products. Some studies proposed foods that were similarly-liked. Pliner et al. (1980) selected three hors d’oeuvres from a pre-test that were equally palatable, while (Spiegel & Stellar, 1990) determined for each participant their three most-preferred sandwiches during an initial session. Nevertheless, in the first study, the authors questioned this equi-palatability of the three hors d’oeuvres because they noticed that they had not been eaten in equal numbers. In the second study, the authors observed significant differences in liking-evaluation between the most-preferred and third-preferred sandwiches. Several studies have compared food intake of variety situations with intake of the no-variety session with the preferred food (Meengs et al., 2012; Pliner et al., 1980; B. J. Rolls, Rowe, & Rolls, 1982). Some studies have also carried out within-subjects tests where volunteers participated in no-variety sessions in which they were presented each alternative. For example, Meengs et al. (2012) carried out a study where subjects participated in one variety session and in three no-variety sessions where they were served with each of the three vegetables. Then, the food intake of variety situations was compared with the mean intake of the no-variety sessions.

The issue of a cofounding effect of preference has also been addressed in studies evaluating the choice effect. Among the five studies presented in **Table 2**, three of them controlled the initial liking of the products (Altintzoglou et al., 2015; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Prior to their main studies, Altintzoglou et al. (2015) and Rohlf's Domínguez et al. (2013) selected two vegetables (zucchinis and green beans) and two fishes (cod and salmon), respectively, that were on average equally-liked for the all group. In their study, Zeinstra, Renes, et al. (2010) selected at the individual level (i.e. for each child) two vegetables that he/she similarly liked (numbers 3-4 of the preference rank order).

3.2.2.4. Conclusion

This overview of the literature on variety and choice effects shows that it is often difficult to disentangle them. When providing simultaneous variety, an implicit choice occurs. When providing choice and allowing people to choose several foods, a variety effect also occurs. According to our definition, both choice and variety are involved in this situation. In their literature review, Remick et al. (2009) considered choice as an external moderator of the variety effect. They defined it as “the ability of participants to choose what they would like to eat as opposed to being offered only a specific food”.

In other studies investigating the choice effect on food intake, the choice situation was considered as the addition of alternatives. For example, in studies that aimed at improving the meal experience for nursing home residents, the food presentation was organized to enable residents to serve themselves (Kremer et al., 2012; Remsburg et al., 2001). The Kid Choice and Cafeteria Power Plus programs provided a wider choice of fruit and vegetables by increasing the number of alternatives in the lunch line (Hendy et al., 2005; Perry et al., 2004). In these studies, “choice situations” were not precisely described, and it was not mentioned whether people had the opportunity to select several items. If participants did have the opportunity to choose several foods, we assume that a variety effect would also have occurred.

Table 2. Overview of studies investigating the effects of variety and choice on food liking and/or food intake (“*Subject*” column: *F*: Female; *M*: Male; “*Design*” column: *WS*: Within subject; *BS*: Between subjects; “*Variety*” column: *Sim.*: Simultaneous variety; *Seq.*: Sequential variety; “*Choice*” column: *Exp.* : Explicit choice; *Imp*: Implicit choice)

References	Subjects	Food	Design	Description of the test conditions	Variety	Choice	Hedonic control	Results
VARIETY								
Pliner et al., 1980 – exp1	72 adults (M)	3 Hors d’oeuvres (different food types and fillings)	BS	Variety: 3 different hors d’oeuvres were served on the same plate	Sim.	Imp.	A pilot study determined 3 equally palatable hors d’oeuvres. The equi-palatability was not found in the main study. Intake in the variety was compared with intake of the preferred food.	Greater intake in the variety condition
				Control: the same hors d’oeuvres were served on the plate	No	No		
Rolls et al., 1981- exp1	36 adults (F)	4 Sandwiches (different fillings)	WS	Variety: 4 different fillings were served in the 4 successive courses	Seq.	No	For the control condition, intake of people receiving their favorite food was compared to intake of people receiving their least favorite food.	Greater intake in the variety condition
				Control: the same filling was presented throughout the 4 successive courses	No	No		
Rolls et al., 1981- exp2	24 adults (F+M)	3 Yogurts (different flavors, color, texture)	WS	Variety: 3 different flavors were served in the 3 successive courses	Seq.	No	Each volunteer carried out a control session with each of the flavors. The mean intake of the 3 control sessions was compared to the intake of the variety session. Intake of variety session was compared to intake of the control session with preferred food.	Greater intake in the variety condition
				Control: the same flavor was presented throughout the 3 successive courses	No	No		
Rolls et al., 1981-exp3	24 adults (F)	3 Yogurts (different flavors)	WS	Variety: 3 different flavors were served in the 3 successive courses	Seq.	No	Each volunteer participated in a control session with each of the flavor.	No differences in intake
				Control: the same flavor was presented throughout the 3 successive courses	No	No		
Rolls et al., 1984	48 adults (F+M)	4-course menu (different meal components)	WS	Variety: 4 different products were served in the 4 successive courses	Seq.	No	Non specified	Greater intake in the variety condition
				Control: the same component was presented throughout the 4 courses	No	No		
Spiegel et al., 1990	27 adults (F)	3 Sandwiches (different fillings)	WS	Variety 1: 3 different fillings were served in the 3 successive courses	Seq.	No	For each subject, the three most-preferred sandwiches were the three determined in a first session, but there were significant differences in liking between the most-preferred and third-preferred.	Greater intake in the variety 2 condition
				Variety 2: 3 different fillings were simultaneously served in the 3 courses	Sim.	Imp.		
				Control: The middle-preferred sandwich was served throughout the 3 courses	No	No		

References	Subjects	Food	Design	Description of the test conditions	Variety	Choice	Hedonic control	Results
Meengs et al., 2012	66 adults (F+M)	3 Vegetables (different color, texture, flavor)	WS	Variety: 3 vegetables were served in the same course Control: 1 vegetable was served in the dish	Sim. No	Imp. No	Each volunteer carried out a control session with each of the flavors. The mean intake of the 3 control sessions was compared to the intake of the variety session. Intake of variety session was compared to intake of the control session with preferred food.	Greater intake in the variety condition
Bucher et al., 2014	100 children (F+M)	2 Vegetables (different color, texture, flavor)	BS	Variety: children served themselves 2 vegetables on the same plate Control: children served themselves 1 vegetable on the plate	Sim. No	Imp. No	Hedonic evaluation of the food tested.	Greater expected intake in the variety condition
CHOICE								
King et al., 2004	207 adults (F+M)	2 flavors of iced tea, of salad dressing and pizza	BS	Choice: choice from a menu of 2 flavors of iced tea, salad dressing and pizza Control: 1 flavor of iced tea, salad dressing and pizza was served	No No	Exp. No	Not specified	Higher liking only for salad dressing in choice condition
King et al., 2008	389 adults (F+M)	6 Salad dressings	BS	Choice: choice of 3 dressings from a list of 6 salad dressings Control: 3 salad dressings randomly assigned and presented according to a monadic procedure	Yes Seq.	Exp. No	Non specified	Higher liking in choice condition
Zeinstra et al., 2010	303 children (F+M)	2 Vegetables (different color, texture, individual selection)	BS	Choice 1: choice of one vegetable before receiving the dish (menu) Choice 2: 2 vegetables were served on the same plate Control: 1 vegetable was served on the plate	No Sim. No	Exp. Imp. No	Each child was assigned 2 vegetables that he equally liked.	No differences in intake
Rohlfs Dominguez, 2013	91 children	2 Vegetables (different aspects and texture)	BS	Choice 1: choice of one vegetable before receiving the dish Choice 2: 2 vegetables were served on the same plate Control: 1 vegetable was served on the plate	No Sim. No	Exp. Imp. No	Two vegetables equally-liked by the group of children were selected.	Greater intake in the 2 choice conditions
Altintzoglou et al., 2015	136 children (F+M)	2 Fishes	BS	Choice: choice of 1 fish plate displayed on trays Control: 1 fish was served	No No	Exp. No	Two fishes equally-liked by the group of children were selected.	Higher liking in choice condition

3.3. The variety effect

The previous literature review showed that initial studies investigating variety effects used very simple paradigms with simple foods (e.g. sandwiches, yogurts). More recently, variety has been investigated as an underlying strategy to encourage people to consume healthy foods or encourage a certain population to prevent undernutrition. It has been used as a strategy to encourage the consumption of fruit and vegetables in adults (Meengs et al., 2012) and children (Bucher, Siegrist, & van der Horst, 2014). Bucher et al. (2014) used a “fake food” paradigm to investigate the variety effect of vegetables as a side dish for pasta and chicken, where children had the opportunity to serve themselves each component of the meal. For 35 years, most of the studies investigating variety have focused on adults. Recent studies have investigated the effect on more specific populations such as children (Bergamaschi et al., 2015) or elderly women suffering poor appetite (Wijnhoven, van der Meij, & Visser, 2015).

3.3.1. Effects on food intake

Table 2 also highlighted that most of the studies displayed an increasing effect of providing variety on food intake. Indeed, the variety effect has been defined as “an increase in amount of food consumed when people are exposed to multiple foods with different sensory characteristics” (Keenan, Brunstrom, & Ferriday, 2015). In their review, McCrory, Burke, & Roberts (2012) found an average increase of 22 % in food intake (amount or energy) when providing several foods within a meal (based on 10 within-subject design studies). B. J. Rolls, Rowe, et al. (1981) showed an intake increase of 19.5 % when providing 3 yogurts in three successive courses that varied in flavor, compared to a situation where the same yogurt was served throughout. Regarding the previous debate, it is interesting to note that this increase was still significant (+12.6 %) when the intake in the variety situation was compared to the intake of the most preferred food in the no-variety condition. Spiegel and Stellar (1990) showed that participants ate 31 % more when they were provided 3 sandwiches with different fillings on a plate than when they were served the same sandwiches. Indeed, these results showed that both sequential variety and simultaneous variety, which also involved an implicit choice, may lead to an increase in food consumption.

3.3.2. Mechanisms of the variety effect within a meal

3.3.2.1. Sensory-specific satiation

In 1996, M. M. Hetherington carried out an experiment on 57 volunteers who were initially presented a plate of cheese on crackers, and then were subsequently offered the choice of receiving a different second course (chocolate), a second course with the same food, or no second course. After the first and the second courses, volunteers had to specify the main reason for stopping. The main reason for

stopping the first course was “I got tired of eating that food” (40 %), while the main reason for stopping the second course was “I felt full” (48 %). This study then showed that meal termination is not necessarily due to a decline in hunger but also to a sensory fatigue, especially for the first course of a meal. After deciding to stop eating the first course, people were still ready to eat another food, as results of this study also showed: 78 % of the volunteers who ate a second course decided to eat another food type for their second course. In 1981, B. J. Rolls, Rolls, Rowe and Sweeney explored the change in pleasantness of the food that had been eaten compared to uneaten food. Thirty-two adults were served with one food (among 8) and asked to eat as much as they wanted. Before and after the consumption of this food, volunteers rated the pleasantness of the taste of 8 foods. Results showed a greater decrease in pleasantness for taste of the eaten food-types than for the uneaten. Sensory-specific satiation (SSS) has been defined as a “change in liking for eaten versus uneaten foods or a change in liking for similar foods that are comparable on sensory qualities versus similar foods that differ on these sensory qualities” (Remick et al., 2009). As specified by Raynor and Epstein (2001), the SSS is more precisely a decline in liking of an eaten food. It is also important to notice that this definition suggests that foods that have similar sensory characteristics are also affected to a lesser extent by the decline in pleasantness. In their study, B. J. Rolls, Rolls, et al. (1981) showed that when eating sausages, a decline in the pleasantness did not only occur for the sausages, but also to a lesser extent in the liking of chicken (meats), while there was an increase in the pleasantness of cookies, raisins and banana (sweet foods). While initial studies investigated the pleasantness of taste, further studies have shown that this decline in pleasantness occurs with several sensory properties such as taste, texture, appearance and smell, as highlighted by M. Hetherington, Rolls and Burley (1989). Sensory-specific satiation is specific to the sensory properties of a food and not specifically to its post-ingestive consequences (M. Hetherington et al., 1989; E. T. Rolls & Rolls, 1997).

Therefore, considering the specific decrease in pleasantness for a specific eaten food, providing a different uneaten food would result in greater intake. In a second experiment, B. J. Rolls, Rolls, et al. (1981) showed a correlation between the decline in liking and the amount consumed in a second course. Twenty-four volunteers were served either the same food for two courses or two different foods for two courses. Participants who received a different food in the second course ate more during the second course. Sensory-specific satiation and variety effect have been shown to be transient: they occur a few minutes after the consumption of the food and progressively return to an initial level 1 hour after (M. Hetherington et al., 1989; B. J. Rolls, Rolls, et al., 1981).

3.3.2.2. Anticipated variety evaluation

While sensory-specific satiety occurs for a specific food once it has been eaten, the variety effect may also be explained by a phenomenon that occurs before eating any food, particularly during the pre-meal planning. In 2013, Wilkinson, Hinton, Fay, Rogers and Brunstrom showed that when providing a

sequential variety of foods, people increased their anticipation of pleasantness and selected larger portions. Participants were presented pictures with either the same dish or two different dishes (sour and sweet) for a two-course meal. Volunteers rated the expected pleasantness for the second course and chose the portions, for either both courses or for only the second course. Results showed that volunteers expected higher pleasantness and selected larger portions for the second course or for both courses in variety situations compared to no-variety situations. The presentation of a simultaneous variety of foods also affected the perceived quantities and expected satiation. In a matching-task study, where participants had to fill a bowl of candies as a reference sample, Redden and Hoch (2009) observed that people poured 12 % more candies when they were presented with multicolored candies compared to monocolored candies. Keenan et al. (2015) showed that the expected satiation decreased when the number of different items presented increased (**Figure 9**). The decrease in perceived quantities and expected satiation in the presence of simultaneous variety would be explained by the fact that people tend to use simple heuristics in estimating the quantities. It has been suggested that quantity perception relies on how an area is occupied; when presented different items, people tend to focus on one type because it appears more difficult to consider the whole collection (Redden & Hoch, 2009). Keenan et al. (2015) also observed that for a high-variety assortment (more than three different items) the expected satiation would be likely based on the perceived volume of the assortment (volume-based heuristics) (**Figure 9**). These studies confirm the idea that the variety effect would be anticipatory and does not only occur during consumption. It is therefore expected that the anticipatory effect of variety would lead to larger served and consumed portions. It has notably been shown that pre-meal planning determines portion size (Brunstrom, 2014). Nevertheless, these studies did not evaluate the effect of anticipatory variety on real consumption.

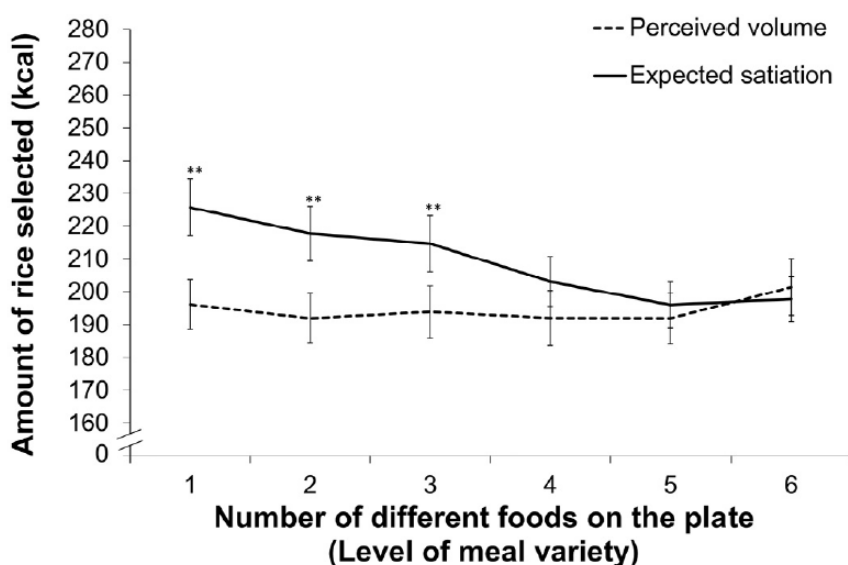


Figure 9. Volume-based heuristic satiation: mean (associated with their SEM) expected satiation and perceived volume scores assessed by matching each level of food variety presentation with an amount of rice. For each level of meal variety, perceived and expected satiation are compared (** $p < 0.001$) (Keenan et al., 2015)

The increase in food intake when provided a variety of foods may be explained by two mechanisms that occur before eating as well as during food consumption. During pre-meal planning, variety affects cognitive representation of food quantities, which results in an increase in the size of the portions served. During food consumption, variety affects sensory perception by preventing the onset of sensory specific satiation. **Figure 10** provides a summary of both cognitive and sensory effects which occur when offered a variety of food, and which result in an increase in the quantities consumed.

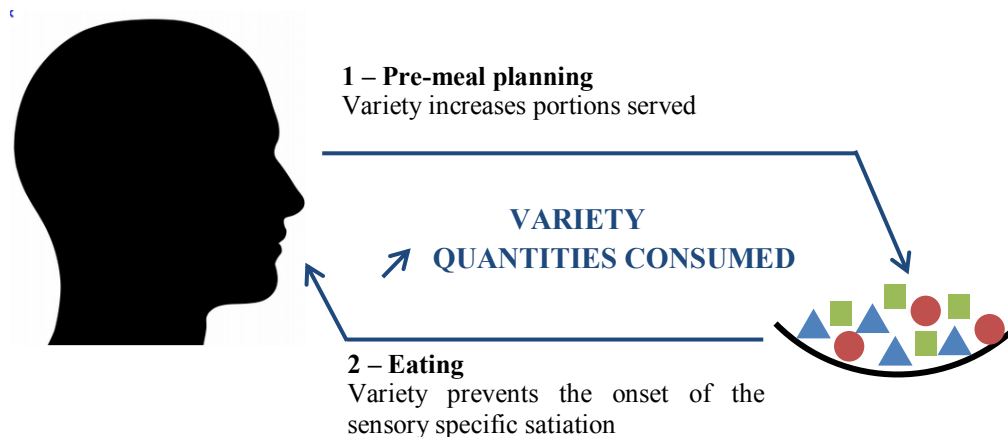


Figure 10. Schema of the mechanisms underlying the variety effect on food intake, occurring before (pre-meal planning) and during the food consumption

3.3.3. Modulators of variety effect

Although many studies have demonstrated an increasing effect of providing choice within a meal on food intake, this impact may be modulated by some factors. In their review, Remick et al. (2009) explored internal and external variety effect moderators as well as sensory-specific satiation. The following section presents some of these modulator factors.

3.3.3.1. Individual characteristics

Remick et al. (2009) reported limited effect of internal factors, excepted for the age.

The increasing effect of providing variety on food intake has been observed at any age: in children (Bucher et al., 2014), adults (Meengs et al., 2012; B. J. Rolls, Rowe, et al., 1981; Spiegel & Stellar, 1990) and elderly individuals (Hollis & Henry, 2007; Wijnhoven et al., 2015). Birch and Deysher (1986) showed that sensory-specific satiation occurs early in life, as observed even with young children (2.5 to 5 years-old). Nonetheless, the magnitude of the variety effect might differ according to age-group, and especially for older ages. In 2007, Hollis and Henry compared the effects of sequential varieties of sandwiches on young adults (mean age of 26 years) and older adults (mean age of 70 years). Both groups of individuals ate more in the variety condition than in the no-variety condition.

Nevertheless, the variety effect was less pronounced for older adults than for young adults. In 1991, B. J. Rolls and McDermott showed that sensory-specific satiation occurred to a lesser extent for elderly individuals than for young adults, especially for the ratings of pleasantness of taste, odor and texture. The modulator effect of age on sensory-specific satiety and variety has not been clearly explained but we may assume that age-related sensory and cognitive changes (e.g. decline in gustatory and olfactory sensitivity, less desire for change) might contribute to the decline in sensory-specific satiety for elderly individuals.

The effect of BMI on the variety effect and SSS has been explored under the hypothesis that obese people are sensitive to external cues regarding food regulation. Despite this assumption, it has been reported that BMI would affect neither the variety effect nor SSS (Brondel et al., 2006; Remick et al., 2009). Nevertheless, in their study on the variety effect, Spiegel and Stellar (1990) showed an increase of 32 % in intake for normal weight individuals and 14 % for overweight individuals in simultaneous variety conditions compared to no-variety conditions but did not observe any difference in intake for underweight individuals. They noticed that underweight individuals had a larger intake in the no-variety condition than normal weight and overweight individuals, especially during the first course, and they also displayed lower scores of restriction. While most of the studies did not find any effect of BMI on either the SSS or on the variety effect, we may assume that psychological traits, especially regarding restriction, might explain the difference observed for underweight individuals in the last study. Nevertheless, Remick et al. (2009) reported in their review that dietary restriction did not modulate the sensory-specific satiation and the variety effect.

Other psychological traits than restraint and dieting status, such as self-control or tendency to seek variety have been explored. Haws and Redden (2013) investigated the impact of self-control on the variety effect by carrying out a series of three studies. As the **Figure 11** illustrates, low self-control participants selected larger amounts of food (chips or candies in Figure 11) in variety situations than in no-variety situations, while the selected amount food did not differ between variety and no-variety situations for high self-control participants. It has been also suggested that high self-control participants displayed a low variety effect because they expected higher satiation; high self-control individuals would presumably better evaluate their satiation even for a varied assortment. This last study also reported that high self-control volunteers did not show a sensory specific satiation as their liking for eaten and uneaten food-types dropped equally.

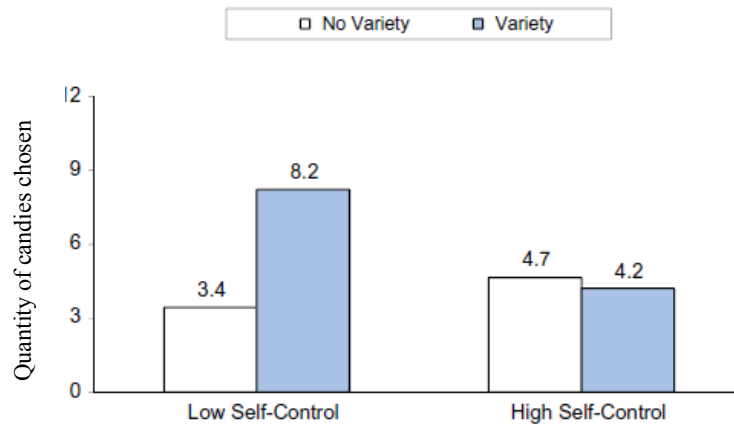


Figure 11. Effects of self-control status on the variety effect: total quantity of candies chosen by presence of variety or no variety for low self-control and high self-control individuals (Haws & Redden, 2013)

3.3.3.2. *External moderators of the variety effect*

Since the sensory-specific satiation phenomenon is related to the sensory properties of a food, the sensory attributes that characterize foods play a role in the magnitude of the SSS effect, and may then modulate the variety effect. Guinard and Brun (1998), for instance, observed that taste-specific satiation occurred to a larger extent than texture-specific satiation. In 1982, B. J. Rolls et al. further investigated how sensory properties of food items may influence the variety effect. They showed that providing a variety of chocolates that only varied in color did not affect food intake. Nonetheless, they found that providing a sequential variety of pasta, which varied only in shape, or a variety of sandwiches, which varied in flavor, increased food intake. This study concluded that the sensory properties of food such as color, shape and flavor did not similarly influence the variety effect.

The degree of sensory differences between food items also influences the magnitude of the variety effect (Marion M. Hetherington, Foster, Newman, Anderson, & Norton, 2006; B. J. Rolls, Rowe, et al., 1981). In their study, B. J. Rolls, Rowe, et al. (1981) observed an increasing effect of variety on food intake when providing 3 different yogurts that varied in flavor, texture and aspect, while they did not observe any effect when providing 3 yogurts that varied only in flavor. They suggested that the variety effect appears when items are sufficiently dissimilar.

In a series of studies, Kahn and Wansink (2004) investigated how the structure of an assortment may modulate the effect of actual variety on the quantities consumed. In their studies, actual variety was the number of different options in the assortments (options that varied in color). The authors compared small assortments and large assortments of candies. The structure of the assortment was manipulated according two structural modalities: the symmetry (all options presented at equal frequencies vs. one option dominating in frequency) and the organization (organized vs. disorganized). In one study, the

authors showed that the symmetry of the assortment moderates the impact of actual variety. They did not find any difference in quantities consumed between small (7-color) and large (10-color) assortments when the assortments were symmetric, (i.e. all the options were represented in equal frequency) but observed an increase in eaten candies between small and large assortments when assortments were asymmetric. (i.e. one option was dominating). A second study also showed that the organization of the options modulated the effect of variety on the consumption. Similar to the previous study, results showed an increase of eaten jelly beans when the number of jelly bean types increased (from 6-color to 24-color), but only for the organized assortment. When the assortment was disorganized, consumption was similar between small and large assortments. Kahn and Wansink (2004) subsequently suggested that modifying the structure of an assortment affects the perception of variety and therefore influences the quantities consumed. **Figure 12** illustrates the model proposed by Kahn and Wansink.

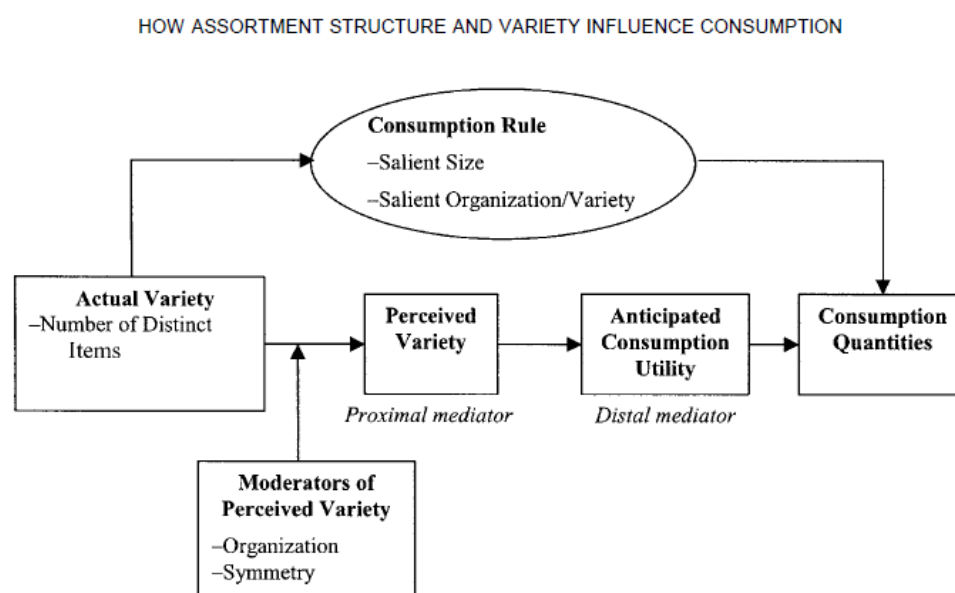


Figure 12. Model of the assortment structure and perceived variety and their impact on consumption (Kahn and Wansink, 2004)

The degree of categorization may also influence the quantities consumed. In his study, Redden (2006) showed that the enjoyment of eating jelly beans decreased faster when participants considered candies as being part of a single general category (e.g. “jelly bean”) than when participants differentiated candies on specific flavor-based subcategories (e.g. “cherry jelly bean”, “orange jelly bean”). When making subcategorizations, individuals would pay more attention to differentiating aspects of the alternatives and then perceive the eating episodes as less repetitive. Consequently, the author suggested that individuals who consider their food divided into categories would be less satiated while eating.

3.4. Conclusion of part 3

Choice and variety are often related. When providing simultaneous variety, an implicit choice occurs. When providing choice and allowing people to select several foods, a variety effect also occurs. Nevertheless, by providing a clear definition of both choice and variety, we better understand the mechanisms underlying the different choice and/or variety situations that may influence food-liking and/or food intake. Indeed, when offering an individual the opportunity to select his/her food, we assume that the individual will display higher satisfaction and motivation to eat, according to the Self-Determination Theory. When presenting an individual with multiple foods that have different sensory characteristics, a variety effect also occurs and leads to an increase in food intake. Nevertheless, in both choice and variety situations, individuals may also have the opportunity to eat their most preferred food and then increase their consumption. Some studies thus paid particular attention in evaluating the choice and variety effects *per se* on food liking and food intake by providing equally-liked foods. In that situation, the choice effect on food liking and food intake would rely on cognitive cues while the variety effect would rely on both cognitive and sensory cues. While several studies have already investigated the effects of variety and choice on food intake, few studies have investigated both effects simultaneously.

1. Research question

Self-Determination Theory posits that providing choice is a way to enhance individual experience of competence and autonomy that results in increased intrinsic motivation and other outcomes such as satisfaction or performance. It is then reasonable to expect that being provided choice of food items would elicit higher food liking and higher intrinsic motivation to eat (i.e. increased food intake) in the context of a meal. Nevertheless, providing choice also gives an individual the opportunity to select and consume its most preferred food which may increase food intake. With the aim of preventing this “preference” effect and to evaluate the cognitive impact of providing choice, we investigate the effect providing choice from among equally-liked food. The impact of providing choice on food liking and food intake during a meal has been subject to recent investigations. Studies focusing specifically on the effect of choice *per se* (i.e. between foods that are equally-liked) were mainly based on children and led to diverging results. The general objective of this thesis is to investigate the effect of providing choice of equally-liked foods during a meal on food liking and food intake in adults through behavioral studies.

According to a review of literature, the choice effect (not necessarily based on food items) may be modulated by the chooser’s individual characteristics and contextual factors such as the assortment structure (i.e. the different choice options). In real-life situations, such as in numerous canteens or cafeterias, consumers have to choose a food from among similar alternatives (e.g. choose a yoghurt from among different flavored yoghurts), whilst in others they have to select a food from among dissimilar alternatives (e.g. choose a starter from among different proposals such as grated carrots, tomato salad, beetroot, etc.). Furthermore, some studies on choice *per se*, carried out on vegetables or fish, suggested that offering choice may improve the consumption of those healthy foods which are not always well-liked (Raghunathan, Naylor, & Hoyer, 2006; Zeinstra, Renes, et al., 2010). It could then be asked whether providing choice would have a similar impact when individuals choose from among foods that are well-liked. The first part of the thesis aims at investigating to what extent the structure of a food product assortment might modulate the effect of providing choice. For that purpose, two behavioral studies were conducted, comparing the impact of choice on food liking and intake under the two following conditions: (1) the degree of similarities between foods (i.e. when choosing a product to consume from among similar products *versus* dissimilar products) and (2) the level of pleasantness of alternatives (i.e. when choosing a product to consume from among pleasant products *versus* choosing from among unpleasant products).

Choice (as the opportunity for an individual to select the food he/she wants to consume) and variety (as the presentation of multiple foods with different sensory characteristics that a person may consume) have been shown to independently increase food intake, although it is not always possible to distinguish between choice and variety effects. Until the present moment, these two factors have been mainly investigated separately, while they may actually co-occur in real-life settings. In fact, in many out-of-home catering situations, individuals have the possibility to choose as many dishes as they desire from among different proposals. The aim of the second part of the thesis is to assess the impact of choice and/or variety on food liking and food intake. Consequently, a third behavioral study was carried out and compared four conditions that may occur in real life: (i) being served one dish (*no-choice/no-variety* condition); (ii) choosing one dish from among several alternatives (*choice/no-variety* condition); (iii) being served several dishes (*no-choice/variety* condition); and (iv) choosing as many dishes as desired from among several alternatives (*choice/variety* condition).

2. The structure of a food product assortment modulates the effect of providing choice on food intake

The first part of the thesis' work investigates to what extent the structure of a food product assortment might modulate the effect of providing choice on food liking and food intake. Sets of apple purees and desserts have been designed with the aim of investigating two characteristics of a food product assortment which may modulate the choice effect on food liking and food intake: (1) the degree of similarities between foods (i.e. when choosing a product to consume from among similar products *versus* dissimilar products) and (2) the level of pleasantness of alternatives (i.e. when choosing a product to consume from among pleasant products *versus* choosing from among unpleasant products).

For that purpose, two sets of semi-solid products were designed to comply with some specific criteria. To evaluate the influence of the degree of similarities, we designed a set of apple purees which varied in one sensory modality (the texture) and a set of desserts which varied in several sensory modalities (color, texture, flavor). To evaluate the influence of the level of pleasantness, individuals should encounter pleasant and unpleasant products: each assortment should elicit contrasting hedonic ratings. To ensure that participants felt they had a choice between products without tasting, products had to appear visually different. Furthermore, this thesis investigates the cognitive effect of providing food choice: to avoid the occurrence of a "preference" effect, individuals should be offered equally-liked foods in choice situation. Finally, in each set, foods had to have similar energy content because we compared food intake between the choice and no-choice situations. The methodologies used to design both assortments are detailed in Appendix 1 of the thesis.

A behavioral study has been carried out on adults who participated in a choice and a no-choice session. Two experiments were carried out using the same design: in the "apple purees" experiment, participants were offered apple purees varying in texture while in the "desserts" experiment, desserts varying in several sensory modalities. In each experiment, participants were either presented pleasant or unpleasant products.

Providing choice led to an increase in food liking in both experiments and an increase in food intake only for the desserts, namely only when the volunteers chose the product to consume from among "not too similar" alternatives. This effect occurred regardless of whether the participants chose the product to be consumed from among pleasant or less pleasant alternatives.

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The structure of a food product assortment modulates the effect of providing choice on food intake

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ABSTRACT

Several authors showed that providing choice may increase food liking and food intake. However, the impact of choice may be modulated by assortment's characteristics, such as the number of alternatives or their dissimilarity. The present study compared the impact of choice on food liking and intake under the two following conditions: (1) when choosing a product to consume from among similar products *versus* dissimilar products; and (2) when choosing a product to consume from among pleasant products *versus* unpleasant products. Two experiments were carried out using the same design: the "apple puree" experiment ($n = 80$), where the volunteers choose from among similar products (apple purees varying in texture) and the "dessert" experiment ($n = 80$), where the volunteers choose from among dissimilar products (fruit dessert, dairy dessert, custard, pudding). During the first session, participants rated their liking for 12 products (apples purees or desserts). Then the participants were divided into a "pleasant" group ($n = 40$) in which volunteers were assigned three pleasant products, and an "unpleasant" group ($n = 40$) in which volunteers were assigned three unpleasant products. Finally, all of the volunteers participated in a choice session – volunteers were presented with their three assigned products and asked to choose one of the products, and a no-choice session – volunteers were served with one product that was randomly selected from among their three assigned products. Providing choice led to an increase in food liking in both experiments and an increase in food intake only for the desserts, namely only when the volunteers chose the product to consume from among "not too similar" alternatives. No effect of assortment's pleasantness was observed.

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1. Introduction

Several authors have demonstrated that choice has a powerful motivating effect: people are more likely to engage in an activity, to succeed in it and to enjoy it if they had chosen it (Patall, Cooper, & Robinson, 2008). According to the self-determination theory, people are naturally inclined to interact with the environment in a way that promotes three psychological needs, the need for competence (i.e., feeling effective), for autonomy (i.e., feeling of being the

perceived origin of a behavior) and for relatedness (i.e. feeling connected to others) (Deci & Ryan, 2002). Social contexts that fulfill these needs will thus enhance intrinsic motivation, namely the desire to carry out an activity for self-gratification (as opposed to extrinsic motivation, the desire to carry out an activity for external rewards). Providing choice is one of the most obvious ways to enhance a person's experience of competence and autonomy (Langer, 1975; Ryan & Deci, 2000). Consequently, the self-determination theory holds that choice should result in positive intrinsic motivation, which in turn leads to higher performance and satisfaction (Patall et al., 2008).

Herb Meiselman and his group were one of the very first to explore the impact of choice on food acceptability. In fact, they observed higher liking scores when participants were asked to

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select three salad dressings to taste among six alternatives (choice condition) than when they were randomly assigned three salad dressings among the six alternatives (no choice condition) (King, Meiselman, & Henriques, 2008). A positive effect of choice on food liking was also observed when participants chose one salad dressing from among two alternatives (King, Weber, Meiselman, & Lv, 2004). However, this study did not reveal any impact of choice on the liking score for pizza or iced tea. More recently, Altintozoglou et al. (2015) observed a positive effect of choice on fish liking when children (11–12 years) chose the fish they wanted to taste from among two alternatives. However, Zeinstra, Renes, Koelen, Kok, and de Graaf (2010b) failed to observe any choice impact on vegetable liking for children (4–6 years).

A survey completed by 242 children (4–12 years) and their parents showed a positive correlation between providing children with a choice and their fruit and vegetable intake (Zeinstra, Koelen, Kok, van der Laan, & de Graaf, 2010a). In fact, choice has been considered to be a contextual factor liable to increase food intake (Kremer, Derks, Nijenhuis, Boer, & Gorselink, 2012; Nijs, Graaf, Kok, & van Staveren, 2006). However, these studies compared a standard meal context with a meal context that was improved not only by providing choice, but also by improving social interaction and the quality of the dining room. Consequently, these studies did not set apart the impact of choice among the impact of other contextual variables. To the best of our knowledge, only two studies have explored the impact of choice *per se* on food intake but provided mixed results. Zeinstra et al. (2010b) did not observe any impact of choice on vegetable intake. This experiment was run with children (Dutch; 4–6 years) who went to a restaurant to have a dinner with their parents. However, Rohlfs Domínguez et al. (2013) observed a 120% increase in vegetable intake when children (Spanish; 4–6 years) were allowed to choose the vegetable that they wanted to consume for their lunch at school from among two alternatives compared to a no-choice situation.

Given the mixed results of the literature, there is a need to explore the conditions in which providing choice impacts food behavior. In fact, the studies reported above were carried out with different age groups (children, adults, elderly), in different contexts (in a laboratory *versus* a real-life situation) and with different food assortments (type of food, number of alternatives). Regarding the latter, it has been established that the impact of choice can be modulated by choice complexity, which depends on the number of alternatives and their dissimilarity (the number of attributes that differentiate the alternatives). A series of studies explored the impact of the number of alternatives on the choice effect. For instance, Rortveit and Olsen (2007) showed a positive relationship between the number of fish alternatives (species, conservation forms, recipes) that the consumer considers when buying and preparing a meal of fish and consumption frequency of fish. Kahn and Wansink (2004) observed higher consumption quantities when children or adults were served with a bowl including 24 colors of candies than when they were served with a bowl including 6 colors of candies. However, Iyengar and Lepper (2000) observed that participants were less likely to purchase a jam when they were offered a choice from among 24 flavors of jam than when they were offered a choice from among 6 flavors of jam in a grocery store. In fact, Scheibehenne, Greifeneder, and Todd (2010) performed a meta-analysis on 63 experiments comparing the impact of small vs large assortments on either self-reported satisfaction with the final chosen option or on whether an active choice was made. The meta-analysis revealed a mean effect of the assortment size of zero, but with considerable variance between studies. In fact, the authors hypothesized that the relationship between the assortment size and the impact of choice on intrinsic motivation and satisfaction should be modulated by some factors such as the ease with which

alternatives can be categorized, the degree of similarity between the alternatives and/or the number of attributes that differentiate the alternatives. For instance, Greifeneder, Scheibehenne, and Kleber (2010) observed that increasing the number of MP3-players (from 6 to 30) led to a decrease in satisfaction only when the MP3-players differed in a high number of attributes (9 vs 4).

Regarding the literature, we hypothesized that the impact of choice on food behavior would be modulated by the characteristics of the food assortment (namely, the different food alternatives to choose from). The current experiment focused on two research questions – the impact of the degree of similarity between alternatives and the impact of the level of pleasantness of alternatives – as they may correspond to real-life situation. In fact, in some situations consumers have to select a food from among similar alternatives (e.g., choose a yoghurt from among different flavored yoghurts), whilst in others they have to select a food from among dissimilar alternatives (e.g., choose a starter from among different proposals such as grated carrots, tomato salad, beetroot ..., a common situation in numerous canteens or cafeterias). Furthermore, as providing choice was suggested to improve the consumption of healthy foods, which are not always well-liked (Raghunathan, Naylor, & Hoyer, 2006; Zeinstra et al., 2010a), one might wonder whether choice would have a similar impact if consumers were offered a choice first between a group of foods that they liked and then between a group of foods that they liked less. Consequently, the present experiment aimed at comparing the impact of choice on food liking and food intake under the two following conditions: (1) when choosing a product to consume from among similar products such as different preparations of a given food, or among dissimilar products such as different foods from a given food category (i.e. the degree of similarity between alternatives); and (2) when choosing a product to consume from among pleasant products or among unpleasant products (i.e. the level of pleasantness of alternatives).

2. General method

2.1. Experimental design

Two independent experiments (Fig. 1) were carried out using the same experimental design but different product assortments: the “apple puree” experiment, where the participants chose from among similar products (apple purees varying in texture) and the “dessert” experiment, where the participants chose from among dissimilar products (fruit dessert, dairy dessert, custard, pudding). For each experiment, the participants took part in three sessions. During the first session, they assessed their liking for 12 food products (apples purees or desserts) using a sequential monadic procedure (the order of products presentation was determined by a Williams Latin square design). Then the participants were divided into two groups: a “pleasant” group ($n = 40$) in which volunteers were assigned three pleasant products and an “unpleasant” group ($n = 40$) in which volunteers were assigned three unpleasant products. Finally, all of the volunteers participated in a choice session and a no-choice session (the order of the sessions was balanced across each group). For the choice session, the participants were simultaneously presented with their three assigned products and asked to choose one of the products. For the no-choice session, the participants were served with one product that was randomly selected from among their three assigned products.

2.2. Participants

Two different panels of healthy and normal weight volunteers

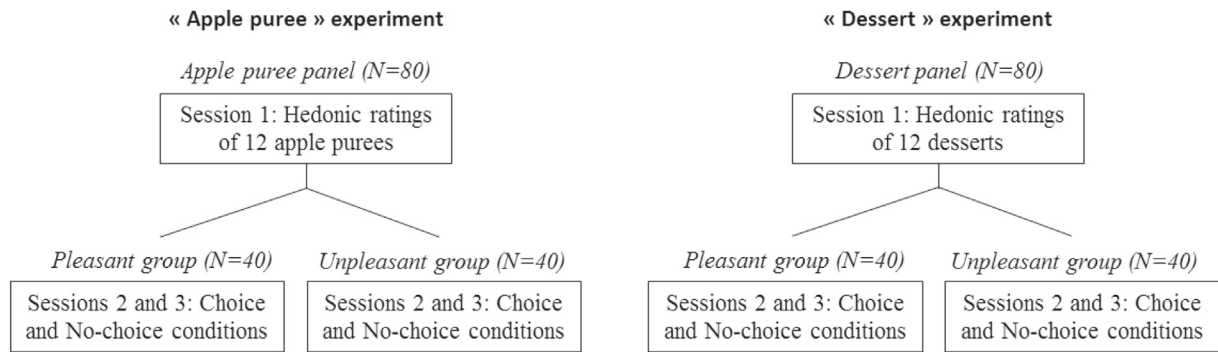


Fig. 1. Overview of the experimental design.

were recruited (one for the “apple puree” experiment and one for the “dessert” experiment) in Paris and surroundings (France) between October 2013 and May 2014. The recruitment criteria were as follows: aged between 18 and 40 years old; having a normal and stable weight (no weight variation greater than 3 kg during the last three months); scoring lower than 10 on the restraint scale and the disinhibition scale of the Three Factor Eating Questionnaire (Stunkard & Messick, 1985); not taking any drugs liable to have an impact on appetite (e.g., corticoids, antidepressants); not on a diet; non-smoker; not abusing alcohol; neither pregnant nor breastfeeding. The power calculation estimated that 40 subjects were necessary in each group (“pleasant” and “unpleasant”) to show a difference of energy intake of 33 g (1/3 of a portion) between a choice and a no-choice situations with a power of 0.80. To ensure that the participants were unaware of the real purpose of the experiment (i.e., to determine the impact of a choice vs. a non-choice situation), they were told that the experiment was designed to study different recipes of desserts (i.e., false pretense). The experimental protocols were approved by the French Ethics Committee for Research Ile de France VII (“apple puree” experiment: #2013-A00340-45; “dessert” experiment #2013-A01746-39). The participants received financial compensation for their participation.

2.3. Products

Two sets of semi-solid products were designed (one for each experiment) to comply with the following criteria: (i) within a set, the difference in energy content between products should not exceed 20 kcal; (ii) within a set, the products should elicit contrasting hedonic responses; and (iii) within a set, the products should be visually different to ensure that participants feel that they have a choice between different products.

2.4. Procedure

Participants took part in three weekly sessions during lunch time (in France, lunch is one of the two main meals of the day, usually including a starter, a warm main dish and a dessert). The participants were asked to have the same breakfast for each test day at least 3 h before the session and not to eat or drink (except water) until the session. For each session, the participants were first served a main course composed of pasta with tomato sauce (Penne Tomate Basilic, Panzani®). During the first session, they were instructed to eat as much pasta as they desired, and the amount that each participant consumed was recorded. During sessions 2 and 3, the participants were served the amount that they consumed during session 1 and asked to eat the full portion (i.e., each participant consumed the same amount of pasta at the beginning of

each session, and this amount was adjusted to each participant's appetite). The sessions were carried out in a room deprived of food references, and the participants sat at individual tables.

Session 1: Liking assessment. After the main course (i.e., pasta) was consumed, the participants were served 30 g of each food product using a sequential monadic procedure. The products were presented in the order determined by a Williams Latin square design. The participants tasted each product and evaluated their liking for the product on a 10-point hedonic scale ranging from “I do not like it at all” (0) to “I like it very much” (10). After each tasting, the participants were requested to take a 45 s break and rinse their mouth out with plain water.

Group assignment and product selection. After the first session, the participants were divided into two groups: a “pleasant” group and an “unpleasant” group. For the pleasant group, each participant was assigned three “pleasant” products, which were three products that the participant had previously scored between 6 and 9 on the liking scale during the first session. For the “unpleasant” group, each participant was assigned three “unpleasant” products that he/she had previously scored between 1 and 4 during the first session. In addition, the three products that were provided to each participant had similar liking scores (i.e., differed by no more than 2 points on the hedonic scale).

Sessions 2 and 3: choice and no-choice conditions. All of the volunteers participated in a choice session and a no-choice session. The order of the sessions was balanced across the panel of volunteers. After consuming the main dish, the participants evaluated their hunger by rating the item “How hungry do you feel now?” on a 100 mm visual analog scale (anchors: “not at all” and “extremely”). Then, for the choice session, the three assigned products (i.e., pleasant products for the “pleasant” group or unpleasant products for the “unpleasant” group) were displayed in front of each participant in a random order. Participants were asked to choose one of the products without tasting them first. Participants could not see each other's choice to rule out any social influence on choice. For the no-choice session, the participants were served with one product that was randomly selected from among their three assigned products. In both sessions, the participants were allowed to eat as much of the product as they desired. They rated their liking of the product at the first spoonful using a 10-point hedonic scale. The participant's food and water intake were measured by weighing the plates before and after consumption (accuracy: ± 1 g).

2.5. Data analysis

The quantities consumed of products were converted into energy intake. For each experiment, the hunger score, water intake, liking score at the first spoonful, apple puree intake and dessert

intake (both weight and energy) were recorded during the choice and no-choice sessions, then submitted to a linear mixed model with the *group* (pleasant vs. unpleasant) and *condition* (choice vs. no-choice) as fixed factors, their interaction, and the *participant* as random factor. Statistical analyses were conducted using R and “nlme” package (R Development Core Team, 2006). Means (M) are associated with the standard error of the mean (SEM). The threshold for significance was set to 5%.

3. Experiment 1 on apple purees

3.1. Participants

Eighty healthy and normal weight volunteers were recruited for this experiment according to the recruitment criteria described in the general method. The characteristics of the volunteers are described in Table 1. No significant difference was observed between pleasant and unpleasant groups for age ($t(78) = 0.43$, ns), BMI ($t(78) = 1.64$, ns) and regarding sex distribution ($\chi^2 = 0$, ns).

3.2. Products

A set of 12 apple purees was designed to comply with the criteria described in the general method. Apple purees that varied in texture were designed by modifying an initial apple puree (Pomme Nature en Morceaux, Sans Sucres Ajoutés, Andros®) through three structural parameters: particle size, pulp content and the addition of apple fragments (Table 2). Previous work already identified particle size and pulp content as key structural parameters to control the texture of apple purees (Espinosa-Muñoz, Symoneaux, Renard, Biau, & Cuvelier, 2012). These products were characterized using a Flash Profile by 10 judges experienced in sensory evaluation (Delarue & Sieffermann, 2004). According to the results, 80% of the descriptors generated by the experts were related to product texture. In addition, the products differed from each other mainly in terms of visual and in-mouth textural characteristics.

In a preliminary experiment, 34 participants (a separate group from the participants in the present study) rated their liking for each apple puree. Results from this preliminary experiment confirmed that all the products within a set elicited distinct hedonic responses: the minimum and maximum hedonic ratings were 2.6 (SEM = 0.2) and 8.2 (SEM = 0.2) respectively.

3.3. Procedure

The experiment followed the procedure described in the general method.

3.4. Results

There was no significant effect (of the *group* or the *condition*) on the hunger score or water intake.

Table 1
Characteristics of the volunteers in the “apple puree” experiment.

	“Apple puree” panel		
	“Pleasant” group	“Unpleasant” group	Total
n	40	40	80
F(n)	27	26	53
M(n)	13	14	27
Age	24.9 ± 4.9 ^a	24.4 ± 4.5	24.6 ± 4.7
BMI	21.9 ± 2.4	21.1 ± 1.7	21.5 ± 2.1

^a Mean ± SD (all such values).

Table 2
Products used in the “apple puree” experiment.

	Formulation parameters			Energy (kcal/100 g)
	Grinding ^a	Added pulp ^b	Apple fragments ^c	
L	1	0	0	56.0
LC	1	1	0	58.9
LF	1	0	1	55.6
LCF	1	1	1	57.6
M	2	0	0	57.0
MC	2	1	0	57.8
MF	2	0	1	57.0
MCF	2	1	1	57.7
Hd	3	–1	0	54.0
HC	3	1	0	58.1
HdF	3	–1	1	56.2
HCF	3	1	1	57.2

^a An initial apple puree was ground at 3 levels (1: weak; 2: medium; 3: strong).

^b 1: addition of pulp to ground apple purees; 0: no added pulp; –1: dilution of ground apple puree.

^c 1: addition of apple fragments to ground apple purees; 0: no added apple fragments.

Liking assessment (session 1). The three selected apple purees for the “pleasant” group have been rated M = 8.1 (SEM = 0.1) and the three selected apple purees for the “unpleasant” group have been rated M = 2.7 (SEM = 0.1). There was an average difference of M = 0.7 (SEM = 0.1) points between the liking scores of the three apple purees in the “pleasant” group and M = 1.0 (SEM = 0.1) points for the “unpleasant” group.

Choice and no-choice conditions (sessions 2 & 3). The linear mixed model revealed significant *group* ($F(1,78) = 24.4$, $p < 0.001$) and *condition* effects ($F(1,78) = 20.8$, $p < 0.001$) on the liking score at the first spoonful, but there was no interaction effect ($F(1,78) = 1.1$; $p = 0.30$). As expected, the participants in the “pleasant” group rated the apple purees more highly (M = 7.5, SEM = 0.1) than the participants in the “unpleasant” group (M = 6.2, SEM = 0.2), based on liking scores. Furthermore, the participants of both groups gave higher liking scores to the apple puree they consumed when they choose it (M = 7.2, SEM = 0.2) than when they were served it without choice (M = 6.5, SEM = 0.2) (Fig. 2A). We did not observe any significant effect (of the *group* or the *condition*) on apple puree intake, based on both weight (Fig. 2B) and energy intake (Fig. 2C).

4. Experiment 2 on desserts

4.1. Participants

Eighty healthy and normal weight volunteers were recruited for this experiment according to the recruitment criteria described in the general method. The characteristics of the volunteers are described in Table 3. No significant difference was observed between pleasant and unpleasant groups for age ($t(78) = -0.08$, ns), BMI ($t(78) = 1.14$, ns) and regarding sex distribution ($\chi^2 = 0$, ns).

4.2. Products

The set of 12 desserts was designed to comply with the criteria described in the general method. Twelve desserts were selected from 16 desserts available in the French market by a free sorting test carried out by 32 untrained subjects (a separate group from the participants in the present study). The results allowed us to select the most dissimilar desserts. These desserts consisted in fruit purees, dairy products, custards and puddings, which differ by several sensory modalities (color, texture, flavor) but have similar nutritional content (Table 4).

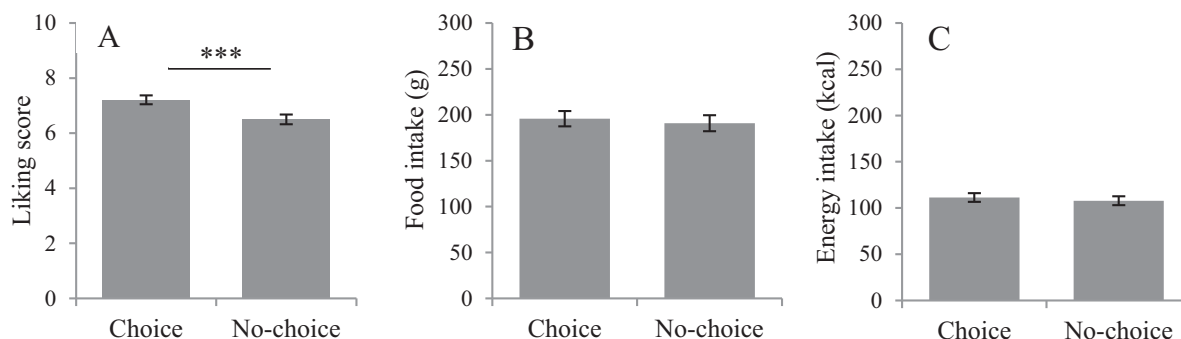


Fig. 2. “Apple puree” experiment: mean liking score of the consumed apple purees (\pm SEM) (A), mean quantity of consumed apple purees (\pm SEM) (B) and mean calorie intake from apple purees (\pm SEM) (C) for each condition (choice and no-choice) (the p -values were obtained by linear mixed model. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$).

Table 3

Characteristics of the volunteers in the “dessert” experiment.

	“Dessert” panel		
	“Pleasant” group	“Unpleasant” group	Total
n	40	40	80
F(n)	28	29	57
M(n)	12	11	23
Age	32.4 \pm 5.4 ^a	32.5 \pm 5.9	32.4 \pm 5.7
BMI	22.5 \pm 2.2	22.0 \pm 1.8	22.2 \pm 2.0

^a Mean \pm SD (all such values).

In a preliminary experiment, 64 participants (a separate group from the participants in the present study) rated their liking for each dessert. Results from this preliminary experiment confirmed that all the products within a set elicited distinct hedonic responses: the minimum and maximum hedonic ratings were 1.6 (SEM = 0.2) and 8.7 (SEM = 0.1), respectively.

4.3. Procedure

The experiment followed the procedure described in the general method.

4.4. Results

There was no significant effect (of the *group* or the *condition*) on the hunger score or water intake.

Liking assessment (session 1). The three selected desserts for the “pleasant” group have been rated $M = 8.1$ (SEM = 0.1) and the three selected desserts for the “unpleasant” group have been rated $M = 2.5$ (SEM = 0.1). There was an average difference of $M = 0.7$ (SEM = 0.1) points between the liking scores of the three desserts in

the “pleasant” group and $M = 1.0$ (SEM = 0.1) points for the “unpleasant” group.

Choice and no-choice conditions (sessions 2 & 3). The linear mixed model revealed significant *group* ($F(1,78) = 48.4$, $p < 0.001$) and *condition* effects ($F(1,78) = 5.5$, $p < 0.05$) on the liking score at the first spoonful, but there was no interaction effect ($F(1,78) = 0.1$, $p = 0.96$). As expected, the participants in the “pleasant” group rated the desserts more highly ($M = 7.8$, SEM = 0.2) than the participants in the “unpleasant” group ($M = 5.5$, SEM = 0.3). Furthermore, the participants of both groups gave higher liking scores to the dessert they consumed when they choose it ($M = 6.9$; SEM = 0.2) than when they were served it without choice ($M = 6.3$; SEM = 0.3) (Fig. 3A).

The linear mixed model also revealed significant *group* (Weight: $F(1,78) = 16.3$, $p < 0.001$; Energy: $F(1,78) = 18.1$, $p < 0.001$) and *condition* effects (Weight: $F(1,78) = 9.2$, $p < 0.01$; Energy: $F(1,78) = 8.5$, $p < 0.01$) on dessert intake, but there was no interaction effect (Weight: $F(1,78) = 1.3$, $p = 0.27$; Energy: $F(1,78) = 1.3$, $p = 0.26$). The participants in the “pleasant” group ate more of the selected dessert (Weight: $M = 217$, SEM = 12 g; Energy: $M = 231$, SEM = 12 kcal) than participants in the “unpleasant” group (Weight: $M = 139$, SEM = 10 g; Energy: $M = 145$, SEM = 10 kcal). Furthermore, the participants consumed more dessert when they had choice (Weight: $M = 192$, SEM = 12 g; Energy: $M = 202$, SEM = 13 kcal) than when they had no choice (Weight: $M = 164$, SEM = 11 g; Energy: $M = 173$, SEM = 11 kcal) (Fig. 3B and C). Therefore, providing choice led to a 17% increase in energy intake compared to not having choice.

5. General discussion

Our study shows that providing choice from among similarly liked alternatives increases food liking. It also appears that having a

Table 4

Nutritional composition of the products used in the “dessert” experiment.

	Energy (kcal/100 g)	Protein (g/100 g)	Carbohydrates (g/100 g)	Fat (g/100 g)
Pistachio Dessert cream	109.1	2.8	18.0	2.9
Chocolate Dessert cream	117.0	3.3	15.3	4.3
Vanilla Dessert cream	114.9	2.8	19.1	3.0
Creamy rice pudding	113.3	2.4	21.5	2.0
Creamy semolina pudding	105.0	3.5	15.9	3.0
Apple puree	103.7	0.3	25.6	<0.1
Raspberry puree	101.6	0.7	24.7	<0.1
Rhubarb puree	107.8	0.8	26.1	<0.1
Vanilla yogurt	99.1	3.3	15.2	2.8
Raspberry-blueberry yogurt	100.1	2.3	10.9	5.2
Prune yogurt	100.0	3.4	14.4	3.2
Cottage cheese	103.9	5.9	4.6	6.9

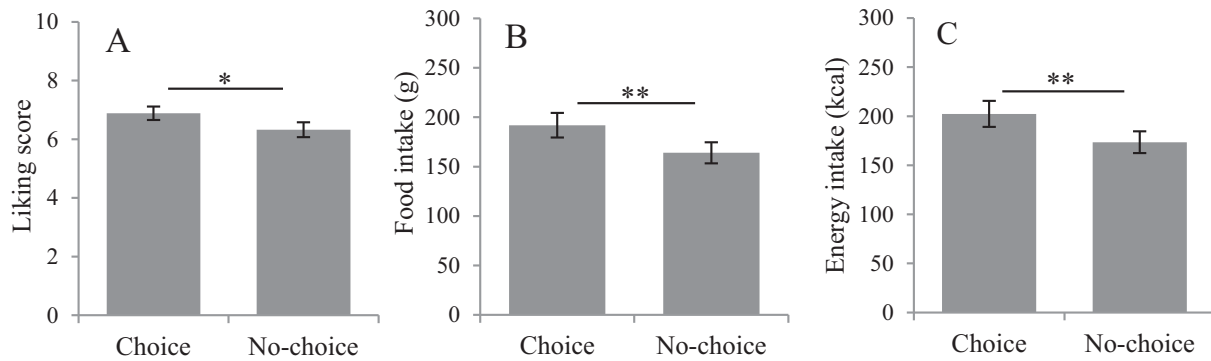


Fig. 3. “Dessert” experiment: mean liking score of the consumed dessert (\pm SEM) (A), mean quantity of consumed dessert (\pm SEM) (B) and mean calorie intake from the dessert (\pm SEM) (C) for each condition (choice and no-choice) (the *p*-values were obtained by linear mixed model. *: $p < 0.05$; **: $p < 0.01$; ***: $p < 0.001$).

choice affects food intake only when participants chose between different foods within a given category (the “dessert” experiment), but not when they chose between different preparations of a given food (the “apple puree” experiment). Concerning food intake, our findings are in line with previous studies showing that providing choice did not always influence food intake. Zeinstra et al. (2010b) did not observe any difference in vegetable consumption when children were allowed to choose a vegetable from two alternatives compared to a no-choice situation. However, Rohlf s Domínguez et al. (2013) observed an approximately 120% increase in intake using the same conditions. The discrepancy between these studies may be explained by the fact that the children ate with their parents in a restaurant, which may have influenced their food behavior in the former study, while they ate with their peers in a more familiar context in the latter study. Regardless of the exact reason for this discrepancy, it is notable that both published studies and our data support the idea that the influence of choice on food intake is vulnerable to contextual factors. In the present experiment, two factors may limit the generalizability of the results. Firstly, the present experiment was run with apple purees and desserts that are traditionally eaten at the end of the meal in France. We have chosen these food products for technical reasons, in order to have enough items liable to elicit mixed hedonic responses whilst displaying similar energy content within a set. However, most of the studies described in the introduction were run with a main dish (Rohlf s Domínguez et al., 2013; Zeinstra et al., 2010b). Secondly, the present experiment was carried out with young adults (18–40 years). However, some authors suggested that the impact of choice may be modulated by age, with young children not having developed choice ability as part of their identity (Altintzoglou et al., 2015) and elderly people not devoting enough attention to all alternatives due to reduced cognitive abilities (Frey, Mata, & Hertwig, 2015). In fact, there is a need for further studies to assess the potential influence of the type of food (e.g., main course vs dessert vs snack), the context of consumption (e.g., in a laboratory vs in a real meal situation) and the individual characteristics such as culture or age.

Our study showed an impact of choice complexity on food consumption behavior. Choice complexity was modulated by the number of attributes that differentiated the alternatives, with alternatives varying in only one sensory modality (texture) in the “apple puree” experiment and several sensory modalities (aspect, flavor, texture) in the “dessert” experiment. We may hypothesize that the participants in the “dessert” experiment perceived a higher degree of variety in their choices than the participants in the “apple puree” experiment. Kahn and Wansink (2004) previously highlighted the influence of the structure of an assortment on the perceived variety of the assortment. These authors also showed

that perceived variety of an assortment may modulate the quantity that is consumed when the subject is given the opportunity to choose between several options. There is also a parallel between our study and a study by Rolls et al. (1981) which explored the effect of providing a variety of foods on food intake. They observed that variety had a greater effect on food intake when participants were served yogurts that varied in taste, appearance and texture, than when participants were served yogurts that varied in flavor only (Rolls et al., 1981). In other words, a product assortment should include products that are “not too similar” to be effective in evaluating both choice and variety. However, if the product assortment becomes too complex (e.g., includes alternatives that differ by too many attributes), then people may have difficulty in processing the information, which could elicit frustration and discourage them from eating. The meta-analysis performed by Scheibehenne et al. (2010) on the impact of the size of the assortments revealed a mean effect of an assortment size of zero but with considerable variance, suggesting that some factors (such as the ease with which alternatives can be categorized, the degree of similarity between the alternatives and/or the number of attributes that differentiate the alternatives) may modulate this effect. Consequently, further research is needed to determine the range of difference between products (not too similar but not too dissimilar) required to identify a significant impact of choice on food intake, although it can be already argued that variation in only one sensory modality (texture in this study) is insufficient.

In addition, we did not observe any influence of the relative pleasantness of the product set on choice effect. As food pleasantness is associated with a large inter-individual variability, a strength of our study is that we selected three similarly liked (“pleasant” groups) or similarly disliked (“unpleasant” groups) products for each participant – as such, different products were assigned to different participants. However, there was a discrepancy between the first session and the choice and no-choice session, especially for unpleasant products. Despite the fact that the participants assigned low liking scores to these products in the first session (2.7 and 2.5 for the apple purees and the desserts, respectively), they rated them higher in the choice and no-choice sessions (6.2 and 5.5 for the apple purees and desserts, respectively). On both occasions, the ratings were based on the consumption of a small amount of product (30 g in the first session and the first spoonful in subsequent sessions). However, the participants rated their liking for 12 samples in the first session, while they rated their liking for only one sample in the choice and no-choice sessions (the sample that they consumed). The sequential monadic procedure used in the first session may have led to hedonic contrast, where “good things making less good things even worse” (Zellner, Allen, Henley, & Parker, 2006; Hayes, DePasquale, & Moser, 2011). This

effect was not symmetric: for the pleasant products, the scores in the choice and no-choice sessions (7.5 and 7.8 for the apple purees and desserts, respectively) were slightly lower than or equivalent to the scores in the first session (8.1 for the apple purees and the desserts). This may be due to the fact that the products were part of the generally well-liked dessert category. Notwithstanding this limitation, the products assigned to the “unpleasant” group remained significantly less liked than the products assigned to the “pleasant” group. This allows us to conclude that choice has a positive impact on food liking and possibly on food intake, regardless of whether the participants chose a product to consume from among pleasant or less pleasant alternatives.

Finally, in addition to the impact of choice on food intake, we also observed an impact of food pleasantness on food intake in the “dessert” experiment, as the participants consumed greater amounts of pleasant desserts than unpleasant desserts, regardless of whether or not they were offered a choice. However, this effect was not observed in the “apple puree” experiment. While several studies have shown a positive relationship between hedonic ratings and food intake (Yeomans, 1996; De Graaf, De Jong, & Lambers, 1999; Bolhuis, Lakemond, de Wijk, Luning, & de Graaf, 2012), other studies concluded that pleasantness had a limited impact on food intake (Bobroff & Kissileff, 1986; de Castro, Bellisle, & Dalix, 2000). It could be argued that, similar to the effect of having a choice, food pleasantness only has an impact on food intake if the degree of difference between pleasant and unpleasant products is large enough. In our study, there was a difference of 2.3 points between the liking scores of the pleasant and unpleasant desserts, while there was a difference of only 1.3 points between the pleasant and unpleasant apple purees.

6. Conclusions

In conclusion, our results confirm that providing choice increases food liking but its influence on food intake is modulated by contextual factors. This effect occurred regardless of whether the participants chose the product to be consumed from among pleasant or less pleasant alternatives. However, the impact of choice on food intake was evident only when the participants chose the product to consume from among “not too similar” alternatives, such as different products from a given food category. We did not observe any effect of choice on food intake when the participant chose the product to consume from among alternatives that varied in only one sensory modality. By considering our results and those from previously published studies, it can be suggested that providing choice or restraining choice may increase the consumption of some foods or limit the consumption of other foods, respectively (see also Altintzoglou et al., 2015). However, before providing recommendations, it is important to look at the conditions and especially the structure of the assortment (such as the number of alternatives and their degree of dissimilarity), in which providing choice has an impact on food intake.

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3. Providing choice and/or variety during a meal: impact on vegetable liking and intake

The aim of this study was to assess the impact of choice and/or variety on food liking and food intake by comparing four conditions that may occur in real life: (i) being served one dish (*no-choice/no-variety* condition); (ii) choosing one dish from among several alternatives (*choice/no-variety* condition); (iii) being served several dishes (*no-choice/variety* condition); and (iv) choosing as many dishes as desired from among several alternatives (*choice/variety* condition).

Both choice and variety increased food liking. Nine participants have been identified as plate clearers because they cleared their plate at each session. Choice led to an increase in the quantities consumed at 8 % for the vegetables when not taking into account plate clearers (and only a tendency when including them). We did not find any variety effect on vegetable intake. We observed no synergy effect between choice and variety on vegetable liking and vegetable intake (i.e. the effect in the *choice/variety* condition was not significantly higher than the effects in the *no-choice/variety* and *choice/no-variety* conditions).

The results of this study are currently submitted for publication:

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TITLE: PROVIDING CHOICE AND/OR VARIETY DURING A MEAL: IMPACT ON VEGETABLE LIKING AND INTAKE

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ABSTRACT

Out-of-home catering services frequently offer consumers the opportunity to choose their foods from among different proposals and/or provide consumers with a variety of food. The aim of the present study was to assess the impact of choice and/or variety on food liking and food intake. Fifty-nine normal-weight adults were recruited under the condition that they equally liked three vegetable recipes (green beans with butter, zucchinis with olive oil, spinach with cream). Volunteers participated in four sessions at lunch time. In the *no-choice/no-variety* condition, volunteers were served one dish randomly selected from among the three. In the *no-choice/variety* condition, volunteers were served all three dishes. In the *choice/no-variety* condition, participants chose one dish from among the three dishes. In the *choice/variety* condition, volunteers chose as many dishes as they desired from among the three dishes. Results showed that providing choice increased vegetable liking and vegetable intake, while offering a variety of vegetables only increased their liking. No synergy effect between choice and variety was observed on vegetable liking and vegetable intake (i.e. the effect in the *choice/variety* condition was not significantly higher than the effects in *no-choice/variety* and the *choice/no-variety* conditions).

KEYWORDS

Food choice; food variety; food intake; food liking; plate clearers; eating behavior

HIGHLIGHTS

Providing choice increases vegetable liking.

Providing variety increases vegetable liking.

Providing choice increases vegetable intake.

INTRODUCTION

Nowadays, out-of-home catering provides individuals some degree of freedom regarding food selection: it is common that people select their dishes from among several proposals (e.g. choice of one starter among several) and/or combine several alternatives for the same course (e.g. selecting two side dishes for the main course). Consequently, people often face a choice situation (e.g. making a decision about the food to be consumed) and/or a variety situation (e.g. being exposed to multiple foods). Both choice and variety have been demonstrated to influence food liking and food intake in previous studies.

Food choice is defined as providing the opportunity for an individual to select the food he or she wants to consume (Parizel et al., 2015). Several authors have observed a positive effect of providing food choice on food liking and/or food intake in adults (King, Meiselman, & Henriques, 2008; King, Meiselman, Hottenstein, Work, & Cronk, 2007; King, Weber, Meiselman, & Lv, 2004), children (Altintzoglou et al., 2015; de Wild, de Graaf, Boshuizen, & Jager, 2015; Rohlf's Domínguez et al., 2013; Zeinstra, Koelen, Kok, van der Laan, & de Graaf, 2010) and elderly individuals (Kremer, Derks, Nijenhuis, Boer, & Gorselink, 2012; Nijs, Graaf, Kok, & Staveren, 2006). For instance, Altintzoglou et al. (2015) observed a positive effect of choice on fish liking when children (11-12 years old) chose the fish they wanted to taste from among two alternatives, compared to a no-choice situation in which children were assigned one of the two fishes. Rohlf's Domínguez et al. (2013) observed a 120 % increase in vegetable intake when children (Spanish, 4-6 years old) were allowed to choose the vegetable they wanted to consume for their school lunch from among two alternatives, compared to a no-choice situation. Recently, we observed that providing choice led to an increase in both food liking and food intake when French adults were allowed to choose the dessert they wanted to consume from

among three alternatives, compared to a situation in which they were randomly assigned one of the three (Parizel et al., 2015). Several authors have demonstrated that choice has a powerful motivating effect: people are more likely to engage in an activity, and to succeed and enjoy it, if they had chosen it (Patall, Cooper, & Robinson, 2008). According to the self-determination theory, people are naturally inclined to interact with the environment in a way that promotes three psychological needs: the need for competence (i.e. feeling effective), for autonomy (i.e. feeling of being the perceived origin of a behavior) and for relatedness (i.e. feeling connected to others) (Deci & Ryan, 2002). Social contexts that fulfil these needs will thus enhance intrinsic motivation, namely the desire to carry out an activity for self-gratification (as opposed to extrinsic motivation, related to the desire to carry out an activity for external rewards). Providing choice is one way to enhance a person's experience of competence and autonomy (Langer, 1975; Ryan & Deci, 2000). Consequently, the self-determination theory holds that choice should result in positive intrinsic motivation, which in turn leads to higher performance and satisfaction (Patall et al., 2008). When applied to the subject of food, one can expect that providing the opportunity for an individual to choose the food he or she wants to consume would elicit an increased motivation to eat, as well as greater food enjoyment.

Food variety is defined as providing an individual with foods that differ on at least one sensory characteristic (Raynor & Epstein, 2001). Again, several authors have observed a positive effect of providing food variety on food intake within a meal (McCrory, Burke, & Roberts, 2012; Meengs, Roe, & Rolls, 2012; Pliner, Polivy, Herman, & Zakalusny, 1980; Raynor & Epstein, 2001; Barbara J. Rolls et al., 1981; Spiegel & Stellar, 1990). For instance, Meengs et al. (2012) observed that participants ate more vegetables when served three types of vegetables side by side (simultaneous variety) than when served only one type. Barbara J. Rolls et al. (1981) showed that

participants ate more when offered a variety of food in succession (sequential variety) (sandwiches with four different fillings; three different flavored-yoghurts) than when offered the same food throughout a meal. In their review of literature, McCrory et al. (2012) found an average increase of 22 % in food intake (amount or energy) when providing food variety within a meal (the meta-analysis was based on 10 within-subject design studies assessing sequential and simultaneous variety). It has been argued that providing food variety may prevent the onset of specific-sensory satiation that refers to a drop in pleasantness of an eaten food aroused by its ingestion in contrast to other non-eaten foods. In fact, B. J. Rolls, Rolls, Rowe, & Sweeney (1981) observed that liking decreased more for an eaten food than a non-eaten food and that these changes in liking were highly correlated with subsequent food intake: participants ate more when they were served a different food (the “non-eaten food”) than when they were served the same food (the “eaten food”). Finally, an impact of food variety was also observed during the pre-meal planning, i.e. before the ingestion of any food (Keenan, Brunstrom, & Ferriday, 2015; Wilkinson, Hinton, Fay, Rogers, & Brunstrom, 2013). Wilkinson et al. (2013) especially showed that participants increased their anticipated pleasantness and selected a larger portion to eat when provided with a sequential variety of foods compared to a no-variety condition.

Literature then shows that providing food choice or providing food variety may increase meal enjoyment and food intake. Until the present moment, these two factors have been mainly investigated separately, while they may actually co-occur in real-life settings. In fact, in many out-of-home catering situations, individuals have the possibility to choose as many dishes as they desire from among different proposals for their meal. Consequently, the aim of the present study was to assess the impact of choice and/or variety on food liking and food intake during a lunch. Specifically, four conditions that may occur in real life were compared: (i) participants were

served with one dish randomly selected from among three alternatives (*no-choice/no-variety* condition); (ii) participants chose one dish from among three alternatives (*choice/no-variety* condition); (iii) participants were served with the three dishes (*no-choice/variety* condition); and (iv) participants chose as many dishes as they desired from among three alternatives (*choice/variety* condition).

MATERIALS AND METHODS

The food products

Three green vegetable recipes were selected from 27 recipes by an on-line questionnaire carried out by 205 French adults (a separate group from the participants in the present study). For each recipe, these adults were asked to indicate if they had already tasted it and then to rate their liking according to a 10-point hedonic scale ranging from “I do not like it at all” (0) to “I like it very much” (10). They were also asked to indicate their frequency of consumption (“more than 5 times per year”; “between 1 and 5 times per year”; “less than one time per year”). The results allowed us to select recipes that are commonly eaten and similarly liked by French adults. These recipes consisted in green beans with butter (mean liking: $M=7.4$, $SEM=0.1$), zucchinis with olive oil (mean liking: $M=7.7$, $SEM=0.2$) and spinach with cream (mean liking: $M=7.4$, $SEM=0.2$).

The green beans (extra-fine frozen green beans, Thiriet®), the zucchinis (frozen zucchinis, Thiriet®) and the spinach (frozen spinach leaves, Thiriet®) were cooked in a pressure cooker at 1 bar for 90 sec, 130 sec and 85 sec, respectively. Then, they were seasoned with butter (1.6 g per 100 g of cooked green beans), olive oil (3.4 g per 100 g of cooked zucchinis) or 30 %-fat cream (7.9 g per 100 g of cooked spinach), respectively. The amount of fatty ingredient added in each

dish was adjusted so that the difference in energy content did not exceed 20 kcal while still fitting typical French culinary habits. Lastly, all the vegetables were seasoned with salt (0.15/100 g) and pepper (0.035/100 g). The nutritional content of each dish is displayed on **Table 1**. The dishes were prepared 2 hours before each meal and reheated in a microwave just before being served, the serving temperature being between 50 and 60°C.

Table 1 about here

Participants

Fifty-nine healthy and normal weight volunteers were recruited from Dijon (France) and its surroundings during the first semester of 2015. The recruitment criteria were as follows: aged between 18 and 40 years old; having a normal and stable weight (BMI between 18.5 and 26 kg/m² and no weight variation greater than 3 kg during the last three months); scoring lower than 14 on the restraint scale and lower than 12 on the disinhibition scale of the Three Factor Eating Questionnaire (Stunkard & Messick, 1985) (Harden, Corfe, Richardson, Dettmar, & Paxman, 2009); not taking any drugs liable to have an impact on appetite (e.g. corticoids, antidepressants); not on a diet; non-smoker; not abusing alcohol; neither pregnant nor breastfeeding; not allergic to any ingredients proposed during the study and having already tasted the three selected vegetable recipes. Furthermore, candidates were asked to rate their liking for the three selected recipes (green beans with butter, zucchinis with olive oil, spinach with cream) on a 10-point hedonic scale in an on-line questionnaire. To be recruited, a candidate had to have similar liking scores for the recipes (i.e. the liking scores of the three recipes differed by no more than 2 points on the hedonic scale) and could not have rejected any of the recipes (i.e. the liking scores should be higher than 2 points for the three recipes).

With the aim of preventing any biases due to change in their behavior, participants were unaware of the real purpose of the experiment (i.e. to study the impact of choice and/or variety on food liking and food intake) and were told that the experiment was designed to study the influence of tea on satiety. The experimental protocol was approved by the French Ethics Committee for Research CPP Est I (#2014-A01709-38). The participants received financial compensation for their participation.

Experimental design

Participants took part in four sessions during lunch (the order of the sessions was balanced across participants according to a Williams Latin square):

- a *no-choice/no-variety* session (NC/NV): the participant was served one vegetable dish that was randomly selected from among the three vegetable dishes;
- a *choice/no-variety* session (C/NV): the participant was simultaneously presented the three vegetable dishes and asked to choose one of the three;
- a *no-choice/variety* session (NC/V): the participant was served the three vegetable dishes side by side;
- a *choice/variety* session (C/V): the participant was simultaneously presented the three vegetable dishes and asked to choose as many dishes as he or she desired.

Sessions were separated by at least 4 days.

Procedure

The participants were asked to have the same breakfast each test day at least three hours before the session and not to eat or drink (except water) until the session (sessions started at 12:00). For each session, the participants were served a main course composed of vegetables and ham

(Monique Ranou®). For the choice condition (C/NV and C/V), the three vegetable dishes were displayed in small portions in front of each participant in a random order. The participants were asked to choose one of the dishes (C/NV) or as many dishes as they desired (C/V) without tasting them first. They could not see one another's choices in order to rule out any social influence on choice. Whatever the condition, the participants received 400 ± 2 g of vegetables: when they were served one vegetable dish (NC/NV, C/NV and when a participant chose one dish in C/V), they were given 400 ± 2 g of this dish; when they were served two vegetable dishes (when a participant chose two dishes in C/V), they were given 200 ± 2 g of each dish; when they were served three vegetable dishes (NC/V and when a participant chose three dishes in C/V), they were given 133 ± 2 g of each dish. The participants were allowed to eat as much vegetables as they desired. A second helping was systematically proposed to participants who finished their plate.

During the first session, the participants were instructed to eat as many slices of ham as they desired, and the amount that each participant consumed was recorded. During the following sessions, the participants were served the amount of ham that they had consumed during session 1 and were asked to eat the full portion. Each participant then consumed the same amount of ham with vegetables throughout all the sessions. After the main course, the participants were served a 400 g portion of apple puree (Compote de Pommes Morceaux Andros®) and were allowed to consume the quantity they desired. At the end of each session, they were offered a cup of tea that varied in flavor throughout the four sessions. At each session, participants were offered mineral water (Evian). The sessions were carried out in a room deprived of food references and the participants sat in individual booths.

Measurements

The participants' food and water intake was measured by weighing the plates before and after consumption (accuracy: ± 1 g). The participants rated their feeling of hunger on a 100 mm visual analog scale ranging from "I am not at all hungry" to "I am extremely hungry" before eating, after the main course and after the meal. They rated their liking for the vegetable course, the ham and the apple puree after the meal according to a 10-point hedonic scale ranging from "I do not like it at all" (0) to "I like it very much" (10). The participants also rated their feeling of hunger one hour after the meal to credit the false pretense of the study (i.e. study the influence of tea on satiety), but these data were not analyzed.

At the end of the last session, the participants rated their liking for each vegetable dish on a 10-point hedonic scale. Finally, each participant was weighed and sized.

Data analysis

Main outcomes. Liking scores collected at the end of the meal for the vegetable course (vegetable liking) and the quantities of vegetables consumed (vegetable intake) were submitted to two different linear mixed models:

- A two-factor linear mixed model with *condition* (NC/NV; NC/V; C/NV; C/V) and *session position* as fixed factors and *participant* as random factor. This model enabled the comparison of the four conditions of vegetable presentations.
- A three-factor linear mixed model with *choice* (choice; no-choice), *variety* (variety; no-variety), their interaction and *session position* as fixed factors, and *participant* as random factor. This model would emphasize the occurrence of a choice effect and/or a variety effect by comparing the choice sessions (C/NV and C/V) with the no-choice sessions

(NC/NV and NC/V) and the variety sessions (C/V and NC/V) with the no-variety sessions (C/NV and NC/NV), respectively.

Session position corresponds to the order of the sessions and was taken into account to investigate a possible effect of tiredness throughout the four sessions.

Secondary outcomes. Liking scores collected at the end of the last session for each vegetable dish were submitted to a one-factor linear mixed model with *dish* as fixed factor and *participant* as random factor. Hunger scores collected during the four sessions were submitted to a two-factor linear mixed model with *condition* (NC/NV; NC/V; C/NV; C/V) and *session position* as fixed factors and *participant* as random factor.

Statistical analyses were conducted using R with the “nlme” package for linear mixed models and the “lsmeans” package for post-hoc analyses (without adjustment)(R Development Core Team, 2006). Means (M) were associated with their standard errors (SEM). The threshold for significance was set at 5 %.

RESULTS

Fifty-nine volunteers were initially recruited in this study but two volunteers did not attend all sessions and three volunteers under-estimated their weight (over 26 kg/m²) in the on-line recruitment questionnaire. Their data were removed from the final dataset. In the *no-choice/variety* condition, all the participants tasted at least two vegetable dishes (1 participant tasted two vegetable dishes and 53 participants tasted the three vegetable dishes). In the *choice/variety* condition, 32 and 12 participants chose two and three vegetable dishes, respectively, while 10 participants chose only one vegetable dish. These 10 participants were removed from the final dataset as they were not in a variety condition when eating the main

course (they only had one vegetable dish on their plate). The final dataset included 44 participants (38 women and 6 men), with an average age of 27 years (SD=6.5), an average BMI of 21.7 kg/m² (SD=2.2) and average scores of TFEQ-D and TFEQ-R of 6.1 (SD=2.6) and 6.2 (SD=3.5), respectively.

Among these 44 volunteers, nine participants ate the whole portion(s) of vegetable(s) that was (were) served on their plate throughout the four conditions: 7 participants systematically cleared their vegetable plate for the first helping and did not ask for a second helping; 2 participants systematically cleared the first helping, asked at some sessions for a second helping and likewise cleared it. On average, these participants ate 410 g (SEM=8) of vegetables throughout the four sessions. The tendency to eat the whole portion on one's plate refers to a so-called "plate clearing" behavior (Robinson, Aveyard, & Jebb, 2015). Interestingly, it has been observed that "plate clearers" finish their plate whether they choose the portion or were served the portion (as in the present experiment)(Fay et al., 2011; Hinton et al., 2013; Robinson et al., 2015; Wansink & Johnson, 2015). This behavior is purported to result either from early parental practices (Birch, McPheee, Shoba, Steinberg, & Krehbiel, 1987) or from ethical concerns such as avoiding food wastage (Robinson et al., 2015). It may be hypothesized that plate clearers show little sensitivity to internal signals such as hunger or external signals such as contextual factors: their food intake mainly depends on the quantity of food served on their plate. Consequently, in the present experiment, the statistical analyses were conducted for the whole population (n=44) and for the population without the plate clearers (n=35).

Main outcomes

Table 2 presents the results of the two-factor and three-factor linear mixed models on vegetable liking and vegetable intake for the population with and without plate clearers. A significant *session position* effect was observed on vegetable intake for the whole population (two- and three-factor models) but not for the population without plate clearers. According to post-hoc analysis, vegetable intake was lower in the first session than sessions 2, 3 and 4.

Table 2 about here

Whole population (n=44). The two-factor model revealed a significant *condition* effect on vegetable liking but not on vegetable intake. According to post-hoc analyses, participants gave higher liking scores to the vegetable course in the *choice/variety*, *no-choice/variety* and *choice/no-variety* conditions than in the *no-choice/no-variety* condition (**Figure 1**). The three-factor model revealed significant *choice* and *variety* effects on vegetable liking and an almost significant effect of *choice* on vegetable intake. Participants gave higher liking scores to the vegetable course and tended to eat more vegetables when provided choice (liking: M=7.5, SEM=0.2; intake: M=349 g, SEM=9) compared to the no-choice conditions (liking: M=6.9, SEM=0.2; intake: M=333 g, SEM=11). They also gave higher liking scores to the vegetable course when provided several vegetable dishes in their plate (M=7.5, SEM=0.2) compared to the no-variety conditions (M=7.0, SEM=0.2).

Figure 1 about here

Without plate clearers (n=35). The two-factor model also revealed a significant *condition* effect on vegetable liking and on vegetable intake. According to post-hoc analyses, participants gave

higher liking scores in *no-choice/variety*, *choice/no-variety* and *choice/variety* conditions than in the *no-choice/no-variety* condition, and ate more in *choice/no-variety* and *choice/variety* conditions than in the *no-choice/no-variety* condition (**Figure 2**). The three-factor model revealed significant *choice* and *variety* effects on vegetable liking and a significant *choice* effect on vegetable intake. Participants gave higher liking scores in choice situations (M=7.4, SEM=0.2) than in no-choice situations (M=6.8, SEM=0.2). They also gave higher liking scores to the vegetable course when provided several vegetable dishes on their plate (M=7.4, SEM=0.2) compared to the no-variety conditions (M=6.9, SEM=0.2). Participants ate more vegetables in choice conditions (M=336 g, SEM=10) than in no-choice conditions (M=310 g, SEM=12).

Figure 2 about here

Secondary outcomes

Vegetable dish pleasantness. No significant *dish* effect was observed on the liking scores collected at the end of the last session for each vegetable dish, either for the whole population (green beans: M=6.7, SEM=0.2; zucchinis: M=7.4; SEM=0.3; spinach: M=7.0; SEM=0.3) or for participants without plate clearers (green beans: M=6.5, SEM=0.3; zucchinis: M=7.2; SEM=0.4; spinach: M=7.0; SEM=0.3). There was an average difference of M=2.5 (SEM=0.3) points between the liking scores of the three vegetable recipes for the whole population, and M=2.7 (SEM=0.3) points for the participants without plate clearers.

Hunger sensation. For the whole population, the two-factor model did not any reveal significant *condition* effects on hunger scores collected before eating, after the main course or after the meal. Results revealed a significant *session position* effect before eating ($F(3,125)=3.39$, $p<0.05$), but no effect after the main course and after the meal. Hunger scores before eating at the session 4

(M=82.3, SEM=2.2) were greater than scores at sessions 1 (M=73.3, SEM=2.3) and 3 (M=76.4, SEM=3.0).

For the population without plate clearers, the two-factor model did not reveal any significant *condition* effect on hunger scores collected before eating, after the main course or after the meal. Results revealed significant *session position* effects before eating ($F(3.99)=2.92$, $p<0.05$) and after the main course ($F(3.99)=2.78$, $p<0.05$) but no effect after the meal. Before eating, hunger scores at the session 4 (M=81.3, SEM=2.5) were greater than from scores at sessions 1 (M=72.1, SEM=2.7) and 3 (M=74.1, SEM=3.5). After the main course, hunger scores at the session 1 (M=5.5, SEM=1.5) were lesser than scores at sessions 3 (M=9.6, SEM=1.9) and 4 (M=8.8, SEM=1.7).

DISCUSSION

This study aimed at comparing the effects of providing choice and/or variety on food intake and food liking. Results showed that both choice and variety increase food liking for the population with and without plate clearers. Nevertheless, we only observed an increasing effect of choice on the quantities of vegetables consumed (+8 %) for participants that were not plate clearers (participants who did not clear their plate at each session). We did not find any variety effect on vegetable intake. We observed no synergy effect between choice and variety on vegetable liking and vegetable intake (i.e. the effect in the *choice/variety* condition was not significantly higher than the effects in the *no-choice/variety* and *choice/no-variety* conditions).

Choice and variety are often confounding factors in real-life settings as well as in experimental designs. When offered food choice consumers also face food variety when they can select several alternatives. Conversely, when offered simultaneous variety consumers also have the choice to

eat the foods they desire. To make the choice condition as close as possible to a real-life situation, participants were either asked to choose *one* dish in the *choice/no-variety* condition or *as many* dishes as they desired in the *choice/variety* condition, from among three proposals. This experimental choice led to the removal of 10 participants who choose only one vegetable dish in the *choice/variety* condition as they were not in a variety condition when eating the main course (they only had one vegetable dish served on their plate). Furthermore, to make the variety condition as close as possible to a natural setting, participants were not explicitly asked to consume each of the vegetable dishes served on their plate. Rather, they were free to consume the vegetable dishes they desired. Actually, all the consumers ate at least two vegetable dishes in the variety conditions, but the presence of choice in the variety conditions cannot be ruled out: participants were free to choose the dishes they wanted to consume from among the dishes that were served on their plate. Accordingly, Zeinstra, Renes, Koelen, Kok, & Graaf (2010) and Rohlf's Domínguez et al. (2013) compared a situation in which children were asked to choose one vegetable dish from among two proposals with a situation in which children were served a plate containing both vegetable dishes. The authors likewise acknowledged that the latter situation involved choice in addition to variety. It may be stated that the choice conditions of the present study (*choice/no-variety* and *choice/variety*) accounted for explicit choices where participants had to formulate their decision to the experimenter while the variety conditions (*no-choice/variety* and *choice/variety*) may include an implicit choice component where participants had the opportunity choose their vegetable dishes without stating it clearly. We might then assume that in the last situations, choice would be then less conscious.

In the present study, we observed that nine participants cleared their plate at each of the four sessions. We hypothesized that plate clearers were less sensitive to internal signals (e.g. hunger)

or external signals (e.g. contextual factors) as their food intake mainly depends on the quantity of food served on their plate. The analysis of results from individuals displaying no tendency of plate clearing showed an increasing effect of choice on their intake. These results emphasized that people are differently sensitive to signals of meal termination: when in the same state of hunger, some individuals mainly rely on the portion served on their plate while others are more sensitive to contextual factors, such as having choice.

The impact of choice on food liking and food intake corroborates previous results obtained in similar experimental conditions (Altintzoglou et al., 2015; Parizel et al., 2015; Rohlf's Domínguez et al., 2013). According to the self-determination theory, providing choice fulfills the consumer's needs for competence and autonomy and thus promotes higher intrinsic motivation, which in turn leads to higher satisfaction and engagement (Patall et al., 2008; Ryan & Deci, 2000). However, it has also been argued that the impact of choice on food behavior may result from the fact that offering choice gives consumers the opportunity to choose and consume the food they favor among proposals. In the present experiment, this "preference" effect was minimized by recruiting participants who gave similar liking scores to the three vegetables. Accordingly, liking ratings performed at the end of study did not reveal significant differences between the three vegetable dishes. However, it cannot be ruled out that some participants ate more in the *choice* and *variety* conditions because they were given the opportunity to eat the vegetable dish(es) they individually preferred in these conditions compared to the *no-choice/no-variety* condition.

Results of the present experiment did not show a significant effect of variety on vegetable intake, contrary to what was expected from the literature (Meengs et al., 2012; Barbara J. Rolls et al., 1981; Barbara J. Rolls, Van Duijvenvoorde, & Rolls, 1984; Spiegel & Stellar, 1990). For instance, Meengs et al. (2012) observed an increase in vegetable intake when consumers were

served three vegetables on their plate compared to situations where consumers received a single vegetable. The discrepancy between the results from this study and those in the literature may result from a difference in perceived variety of the assortment. In the present experiment, participants were served three vegetable dishes that varied in shape, taste and texture but not in color (green vegetables), while in the study by Meengs et al. (2012) participants were served three vegetables dishes that also varied in color (carrot, broccoli and peas). In fact, Barbara J. Rolls et al. (1981) observed that variety had a greater effect on food intake when participants were served yogurts that varied in taste, appearance and texture, than when participants were served yogurts that varied in flavor only. Furthermore, Redden (2006) showed that the enjoyment of eating jelly beans decreased faster when participants considered the candies as being part of a single general category (“jelly bean”) than when participants considered the candies as belonging to different flavor-based subcategories (e.g. “cherry jelly bean”, “orange jelly bean”). The author suggested that individuals paid more attention to the differences between the alternatives when achieving subcategorization, and thus perceived the successive eating episodes to be less repetitive. Consequently, consumers who consider their foods as belonging to different subcategories are less satiated. In the present experiment it may be hypothesized that participants considered the three vegetable dishes as belonging to the general category “green vegetables” instead of three different subcategories (i.e. “green beans”, “zucchini”, “spinach”).

CONCLUSION

In conclusion, our results showed that providing choice and variety increased food liking, but only choice increased food intake. Contrary to our expectations, we did not observe any variety effect on food intake and therefore assumed that green vegetables did not arouse enough sensory dissimilarity. The present study did not reveal any synergy effect of providing choice and variety

that might be related to the absence of variety effect. Further experiments using more dissimilar vegetables (varying in texture, taste and also color) would be needed before concluding that choice and variety do not interact.

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TABLE 1

Nutritional composition of vegetable recipes

	Energy (kcal/100g)	Protein (g/100g)	Carbohydrates (g/100g)	Fat (g/100g)
Green beans with butter	56	2.2	9.1	1.2
Zucchini with olive oil	42.5	1.5	3.5	2.5
Spinach with cream	62.8	3.6	2.9	4.1

TABLE 2

Results of the two-factor and three-factor linear mixed model on vegetable liking and vegetable intake for the whole population and for the population without the plate clearers.

Sample	Variable	Model	Factor	n	F	p-value
Whole population	Vegetable liking	Two-factor	condition	124	7.55	<0.001
			session position	124	0.46	0.71
		Three-factor	choice	124	11.55	<0.001
			variety	124	9.19	<0.01
			choice:variety	124	1.75	0.19
			session position	124	0.52	0.67
	Vegetable intake	Two-factor	condition	124	1.63	0.19
			session position	124	3.38	<0.05
		Three-factor	choice	124	3.22	0.08
			variety	124	0.63	0.43
			choice:variety	124	0.91	0.34
			session position	124	3.43	<0.05
Without the plate clearers	Vegetable liking	Two-factor	condition	97	5.69	<0.01
			session position	97	0.32	0.81
		Three-factor	choice	97	9.25	<0.01
			variety	97	6.33	<0.05
			choice:variety	97	1.53	0.22
			session position	97	0.31	0.82
	Vegetable intake	Two-factor	condition	97	2.83	<0.05
			session position	97	2.32	0.08
		Three-factor	choice	97	6.47	<0.05
			variety	97	0.81	0.37
			choice:variety	97	0.77	0.38
			session position	97	2.47	0.07

FIGURE LEGENDS

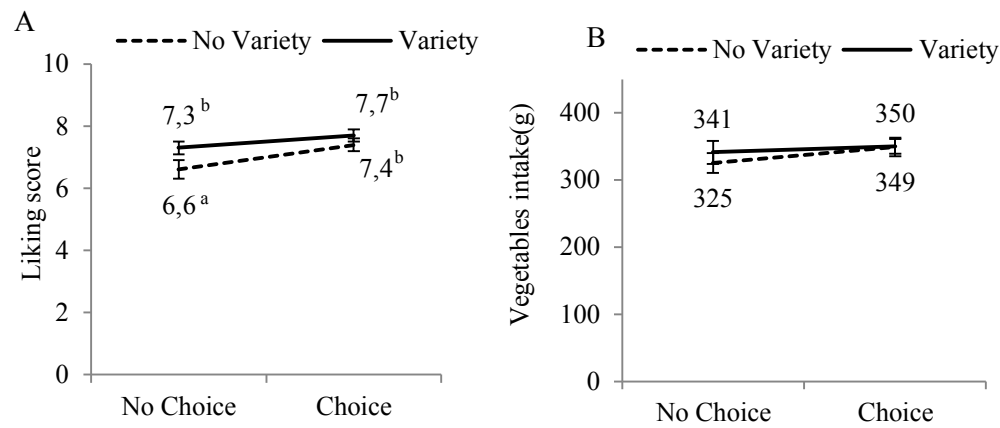
FIGURE 1

Mean liking scores of the consumed vegetable (\pm SEM) (A), mean quantities of consumed vegetable (\pm SEM) (B) for each condition for the whole population. Means with different letters stand for significant differences ($p < 0.05$) (the p-values were obtained from post-hoc analyses (lsmeans package) following the 2-factor linear mixed model that revealed a *condition* effect)

FIGURE 2

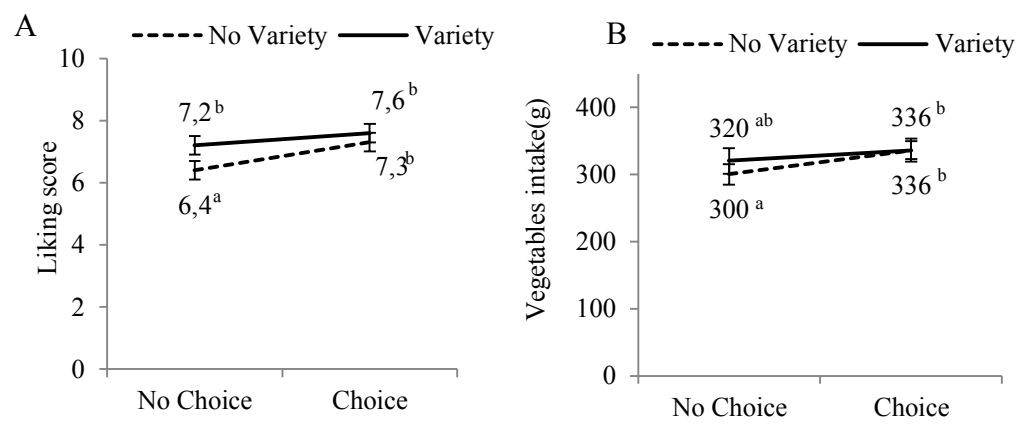
Mean liking scores of the consumed vegetable (\pm SEM) (A), mean quantities of consumed vegetable (\pm SEM) (B) for each condition for the population without the plate clearers. Means with different letters stand for significant differences ($p < 0.05$) (the p-values were obtained from post-hoc analyses (lsmeans package) following the 2-factor linear mixed model that revealed a *condition* effect)

522 **FIGURE 1**



523

524 **FIGURE 2**



525

DISCUSSION AND PERSPECTIVES

The objective of the present thesis was to investigate the impact of providing food choices during a meal on the pleasure of eating and on the quantities consumed. The three behavioral studies carried out on adults confirmed that offering an individual the opportunity to choose their food, even among similarly appreciated items, increased food liking compared to no-choice situations. This positive effect of providing choice on food liking was observed for different food categories (dessert and vegetable dishes). Offering an individual the opportunity to choose their food may also increase the quantities consumed. Nevertheless, the impact of choice and variety (the latter often associated with choice) on food intake appear to be vulnerable to contextual factors such as the structure of the assortment.

Regarding these results, the following section will address three main issues: What are the underlying mechanisms of the choice effect? What degree of similarities should a set of products have to observe an effect of choice and variety on food intake? Should food choice be considered a potential strategy to foster positive food behavior?

1. Studying the impact of providing food choices

1.1. Deciphering the mechanisms

The present thesis investigated the impact of providing choice on food liking and food intake. To the best of our knowledge, only a few studies have investigated this research question. Based on theoretical frameworks drawn from other research fields, Self-Determination Theory assumes that providing food choice enhances a person's experience of competence and autonomy, resulting in an increased satisfaction regarding the chosen food and an increased motivation to eat. Behavioral studies presented in this thesis showed that when providing choice, individuals displayed higher liking regarding the chosen options and also consumed higher quantities. These results are in line with the hypotheses presented since we likewise observed an increase in food liking of the chosen food and, under certain conditions, an increase in food intake when offering choice among three equally-liked foods.

1.1.1. Measure of satisfaction and motivation

In the literature, intrinsic motivation is evaluated by behavioral and/or self-reported measures (Patall et al., 2008). For example, Reeve et al. (2003) assessed the intrinsic motivation of children choosing puzzles through a questionnaire relative to their interest and enjoyment (e.g. "This puzzle is very

interesting”, “The puzzle is fun”) and evaluated the additional time that children spent in pursuing puzzle solving (behavioral measure). In our studies, participants evaluated the liking of the chosen food, and the quantities consumed were subsequently measured. Measuring satisfaction regarding the chosen food (liking) and its subsequent intake might then account for an evaluation of intrinsic motivation, which occurs when choosing a food. Nonetheless, the relevance of these assessments is worth discussing.

First, we notice a discrepancy in the liking evaluation methodologies between the dessert and the vegetable studies. In the first study, participants rated the dessert-liking at the first spoonful, while in the second study, participants evaluated the vegetable-liking at the end of the whole meal (after the apple puree). While the first measure was a real-time hedonic evaluation of the food (i.e. rating was given when tasting that food at the first spoonful) carried out before its consumption, the second one was a postponed measure (i.e. rating performed at the end of the meal) once the product had been eaten. Despite this discrepancy, we observed in both studies an increasing effect of choice on this assessment.

Second, we call attention to the distinction between *liking* and *wanting* (Blundell et al., 2010; Finlayson, King, & Blundell, 2008, 2007). While the former refers to a hedonic evaluation of a food product, the latter refers to the desire to eat a certain food and includes a motivational component. The model presented by Mela (2006) posits that the desire to eat is affected by liking but is also influenced by environmental factors. Hence, a complementary measurement of the desire to eat would have been consistent with the assessment of intrinsic motivation when providing food choices. Regarding behavioral measurement of intrinsic motivation, asking the price that participants would be ready to pay for that food would also have served as a measurement of general motivation, but non-specific to the motivation to eat. A major reason for this lack of measurement is due to the fact that studies were carried out with observational aims, as the impact of providing choice on food behavior had been very little studied until now, especially on adults. We did not want participants to be aware of the study’s real goal, so we avoided asking them complementary questions that might have influenced their behavior.

Finally, we may suggest that further research in neuro-imaging could provide complementary information regarding the underlying mechanisms of the choice effect. Indeed, implicit measurements from neuroimaging could help us decipher whether providing choice influences the affective value and/or the motivation (reward). Research in neuroimaging already uses choice-paradigm with the aim of better understanding the mechanisms of choosing food (Arana et al., 2003; Charbonnier, van der Laan, Viergever, & Smeets, 2015). For example, Charbonnier et al. (2015) carried out an fMRI study to examine the influence of food calorie content (low- vs high-calorie foods) in brain activation when individuals choose between equally-liked foods. To the best of our knowledge, no study has compared

brain responses of individuals making choices with individuals making no-choice, in both food and non-food research fields.

1.1.2. Assessing satisfaction of psychological needs

Our studies do not allow us to draw conclusions regarding deeper mechanisms, either, especially regarding the satisfaction of psychological needs when providing food choices. Regarding the Self-Determination Theory, we assumed that choice would enhance the sense of competence and autonomy, resulting in an increase in intrinsic motivation. Questionnaires have already been developed to assess the satisfaction of psychological needs for either a sport (Gillet, Rosnet, & Vallerand, 2008) (Gillet et al., 2008) or educational context (Amoura, Berjot, & Gillet, 2013). To the best of our knowledge, no questionnaire has been developed for an eating context to assess to what extent food choice impacts satisfaction of the three psychological needs.

1.2. Evaluating the effect of choice *per se*

1.2.1. Influences of contextual factors in liking evaluation

Offering a choice of foods also gives an individual the opportunity to consume their most preferred food. Several studies have shown that eating the most pleasant food leads to an increase in the quantities consumed. With the aim of preventing this effect, both our and previous studies paid attention to providing choice from among food options that were similarly appreciated (Altintzoglou et al., 2015; Rohlfs Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Despite this measure of control, some influence on liking evaluation can be considered. In the two first studies of the thesis, volunteers participated in an initial session where they evaluated the whole set of samples (12 apple purees or 12 desserts which were designed to elicit higher hedonic differences). This session allowed us to select three equally-liked products that were presented in the choice and no-choice sessions. It was not obvious that hedonic rating would remain stable across several sessions, though it has been shown that individuals may display some changes in liking evaluation during the several exposures (Frøst, 2006) or that hedonic ratings may depend on the set of products presented. First, it has been shown that, within a set of stimuli, individuals distribute their responses across almost the full available scale as they might believe that the limits of the scale correspond to the range of stimuli (Lim, 2011). Second, we could not rule out the possible existence of a hedonic contrast, which posits that “good things make less good things even worse (Zellner et al., 2006).

1.2.2. Deciphering choice and variety

As previously mentioned, choice and variety are often associated. This relationship has been investigated in the second experiment of the present thesis and it has been observed that choice does

not only occur when explicitly asking an individual to select the food he/she wants to eat. When being served with a variety of foods, people make implicit choice by selecting the food they eat at each mouthful. We suggested making a distinction between explicit and implicit choices. Nevertheless, we cannot conclude whether people differently perceived explicit and implicit choices, and to what extent it may impact food intake.

Despite the different controls implemented throughout the different studies of the thesis, distinguishing the choice effect *per se* from other effects such as hedonic contrast or the variety effect is not straightforward.

2. Characteristics of a food product assortment: modulation of the choice and variety effects

The present thesis highlights that the assortment of food products plays an important role in the occurrence of both choice and variety effects on food intake. The first part of the thesis emphasizes that providing choice did not alter the quantities consumed when food options varied in only one sensory modality (the texture), while it positively impacted food intake when food options differed in several sensory modalities (color, texture, flavor). The second part of the thesis reveals that offering choice from among three dishes of green vegetables (that varied in appearance, texture and taste) enhanced the quantities consumed. Nevertheless, contrary to our expectations based on the literature, we failed to observe a variety effect when simultaneously providing these same green vegetable recipes on the same plate.

Our work and previous literature highlighted that the choice and variety effect would be vulnerable the degree of similarities of the food options. To the best of our knowledge, no study has clearly estimated the degree of similarity from which choice and variety effects would appear. Based on the second part of this present study, it may be assumed that the threshold degree of similarities from which choice and variety affects food intake would be different: offering three dishes of green vegetables enabled us to observe an effect of choice but no effect of variety on food intake.

2.1. Characteristics modulating the choice and variety effects

On the one hand, the choice effect would rely on cognitive cues, as the increase in satisfaction and motivation would be due to a greater feeling of autonomy and competence (psychological needs). On the other hand, offering a variety of foods would first affect cognitive representations of the food quantities during the pre-meal planning phase, and second, affect sensory perception by preventing the onset of sensory specific satiation when eating. While the effect of choice *per se* would be mostly due to a cognitive process, the variety effect would rely on both cognitive and sensory cues. Based on this

conclusion, we could now investigate how the characteristics of the food product assortment would impact the sensory and cognitive cues and then modulate the choice and variety effects.

Regarding the effect of providing choice (not food-specific), it has been shown that structure of the assortment, such as the number of alternatives, the number of attributes that differentiate the alternatives, the number and distribution of attribute levels may modulate the satisfaction and/or the motivation (Iyengar & Lepper, 2000; Lurie, 2004; Reutskaja & Hogarth, 2009; Scheibehenne et al., 2010). The organization of alternatives into categories of unfamiliar alternatives, and the nature of the attributes that differentiate the alternatives, have also been identified as modulator factors of the choice effect (Chernev, 2005; Markman & Medin, 1995; Mogilner et al., 2008).

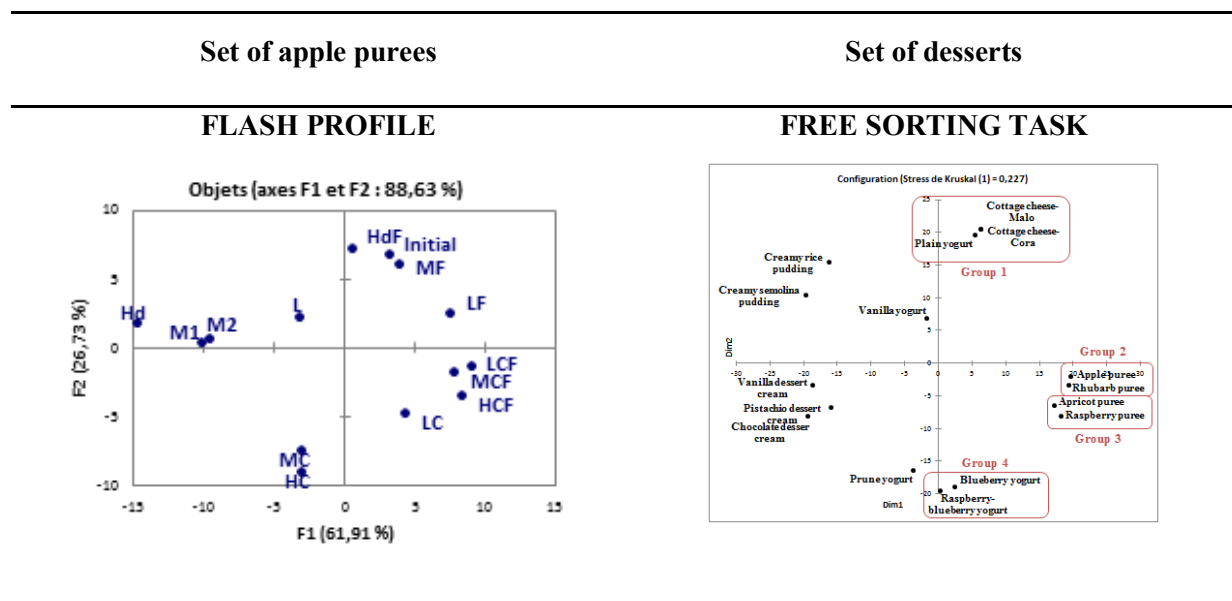
Regarding variety, it has been suggested that the number of food options (Kahn & Wansink, 2004), the number and the nature of the sensory modalities that differentiate alternatives (Guinard & Brun, 1998; B. J. Rolls, Rowe, et al., 1981; B. J. Rolls et al., 1982), the organization of the foods (Kahn & Wansink, 2004), and the categorization (Redden, 2006) influence the magnitude of its effect on food intake. For example, B. J. Rolls et al. (1982) showed that a variety of colors of chocolate do not elicit any variety effect while several shapes of pasta or flavors of sandwiches do.

Hence, similar characteristics of the assortment relative to its structure (number of food options, number of attributes that differentiate the alternatives), its organization (categorization) and its nature (the nature of the attributes that differentiate the alternatives) modulate both choice and variety effects. It is also noteworthy that the choice and variety effect are not necessarily impacted by these characteristics alone, but rather by an interaction of these characteristics (Greifeneder et al., 2010; Kahn & Wansink, 2004).

2.2. Measuring the degree of similarities of an assortment

Until now, no general methodology that enables us to assess the degree of similarity of an assortment and then to compare the degree of dissimilarities of assortment has been developed. Still, some methods allowed us to estimate the similarities of the products. The methods are, however, product-dependent in the sense that there is no single method to evaluate all the product assortments that have to be compared. **Table 3** presents two methodologies that were used in the present thesis. For the set of apple purees, we used a flash profile method as the apple purees belonged to the same category of products. While it initially aimed at describing the assortment, the map of the products highlights the products that are most similar according to sensory modalities. For the set of desserts, we used a free-sorting task during which participants had to sort the products that were similar. These methodologies enabled us to conclude that products were differently perceived within each assortment. Nevertheless, the distances between alternatives presented on each map are relative within the set of products studied.

Table 3. Product map resulting from the flash profile and the free sorting task carried out for designing the of the apple puree and dessert assortments, respectively (detailed in Appendix 1)



Most of the assortment characteristics (e.g. number of alternatives, number of attributes that differentiate alternatives) might be explicitly described by a panel. Some characteristics, though, such as categorization, might be more implicit. In the experiment based on vegetables, we suggested that participants might have categorized the vegetables into the general category “green vegetables” instead of having considered the three vegetables as three different vegetable recipes (zucchinis, spinach and green beans). Indeed, as we noted above, the choice and variety effects are governed by both sensory and cognitive cues and their modulation would then affect such cues. A general methodology should then consider both explicit and implicit characteristics of an assortment.

Interestingly, several approaches have been developed to assess the variety of an assortment. The product-based approach focuses on the degree of dissimilarity between two options across all attributes, while the attribute-based approach focuses on the similarities of attribute levels across the alternatives and the relationship between different attributes (Chernev, 2012). Herpen and Pieters (2002) showed that the attribute-based approach accounted best for individual perception of variety. Nevertheless, the assessment of the assortment variety also relies on a given individual’s perception of variety. It has been shown that some characteristics may influence the perceived variety of an assortment. As Hoch, Bradlow and Wansink (1999) previously observed, Kahn and Wansink (2004) highlighted that the organization of an assortment moderates the perceived variety of an assortment. They demonstrated that when presenting a disorganized assortment of candies, people perceived small (6 different candy colors) and large assortments (24 different candy colors) similarly. In contrast, when the assortment was organized, people perceived the variety of a small assortment to be lower than the variety of the large assortment. It has been also suggested that the categorization of options

may influence the perceived variety of an assortment. (Mogilner et al., 2008) demonstrated that people who were unfamiliar with certain magazines reported greater perception of variety when presented these magazines in 18 rather than 3 categories. It has been suggested that within a category, products are perceived as more similar, while products belonging to different categories are perceived as more dissimilar. Hence, categorization is perceived as a cue that emphasizes differences. It appears that structural factors such as organization or categorization modulate the perceived variety of an assortment. These examples point out that despite the consistent content of an assortment, some presentation factors may modulate individual perception of the assortment.

2.3. Determining an optimum degree of similarities

Regarding the modulator effect, it appears that when an assortment does not display enough dissimilarities, the choice and the variety effect do not occur (Parizel et al., 2015; B. J. Rolls, Rowe, et al., 1981). Nevertheless, it has been assumed that an overly complex assortment might lead to a decrease in satisfaction and motivation when making choice (inverted U-shape), probably due to an overwhelming amount of information that may prevent one from making the optimal decision (Lurie, 2004). Regarding the variety effect, once a threshold of dissimilarity has been reached, the relationship between the degree of dissimilarities and the magnitude of the effect is not clear (linear relationship? Plateau? Inverted U-shape?). We observe, though, that Marion M. Hetherington et al. (2006) failed to find any difference in the magnitude of the variety effect on food intake when providing a variety of foods with congruent tastes and a variety of foods with incongruent tastes: when eating popcorn either sweet or salty, participants were interrupted and ate foods with either congruent flavors (other sweet foods if popcorns was sweet, or other salty products if popcorn was salty) or foods with incongruent flavors (salty foods if popcorn was sweet, or sweet foods if popcorn was salty).

3. Providing food choice: a powerful strategy?

The impact of providing choice has already been recognized as a teaching practice that may improve learning in children, and even a medical strategy that promotes health and well-being. The idea that providing food choice may be an interesting strategy to support positive food behaviors has been a recent issue addressed in research.

The first part of the thesis, based on desserts, emphasizes that providing choice positively influences food intake whether the products were pleasant or unpleasant. It can then be suggested that providing or restraining choice may increase or limit, respectively, the consumption of certain foods. As some healthy foods are under-consumed due to their lack of palatability, we may assume that providing choice among a variety of vegetables or other foods might be an effective strategy to favor their consumption. The second part of the thesis highlights that providing choice among vegetable recipes

has an increasing effect on the consumption of these vegetables. These studies concluded that choice leads to an increase in the quantities consumed at 17 % for the dessert and 8 % for the vegetables. Nevertheless, before providing any recommendations, some important points merit discussion.

3.1. Choice effects in real-setting environments

This study's experiments investigated the effect of providing choice *per se*: individuals were offered choice among similarly-liked products. These experiments were carried out in laboratory conditions. Participants were offered a meal in an environment free of food references, and the individuals could not interact with each other. In more natural contexts such as at a self-service counter or buffet, contextual factors might interact or even compete with the choice effect on the final quantities consumed.

Firstly, a choice situation in natural settings frequently provides an individual the opportunity to find a most preferred food. It has been already reported that eating the most preferred food leads to higher food intake (Bolhuis et al., 2012; De Graaf et al., 1999; Sørensen et al., 2003; Yeomans, 1996). We might then ask whether a synergy effect would occur when providing choice and preference, or whether one effect would have more impact than the other. In this case, further studies are needed to distinguish each effect.

Secondly, portion size has been identified as an important factor that influences the quantities consumed. In the last study on vegetables, we identified individuals with a tendency to clear their plate at all sessions. They may be more likely to trust the served portion and therefore be influenced to a lesser extent to external cues such as choice. Plate clearers are individuals who finish their plate whether they choose the portion or whether they were served a portion (Fay et al., 2011; Hinton et al., 2013; Robinson, Aveyard, & Jebb, 2015; Wansink & Johnson, 2015). This behavior is purported to result either from early parental practices (Birch, McPhee, Shoba, Steinberg, & Krehbiel, 1987) or from ethical concerns such as avoiding food wastage (Robinson et al., 2015). In real-setting environments, people may either determine their desired portion or be served a given portion. In their study, Adams, Pelletier, Zive and Sallis (2005) compared two natural settings where students had the choice of food but had either the opportunity to serve themselves the quantities (self-service salad bar) or were served pre-portioned foods. The authors did not observe any difference in the consumption of fruits or vegetables.

Other factors such as eating with other individuals, price information, and making certain foods more accessible frequently occurs in natural contexts and may influence food intake (Castro & Castro, 1989; Cohen & Babey, 2012). In their studies, de Wild, de Graaf, Boshuizen and Jager (2015), Rohlf's Domínguez et al. (2013); Zeinstra, Renes, et al. (2010) investigated the effect of providing choice of vegetables to children at-home, at canteens and restaurants, respectively. Only the two first studies,

run in a more familiar context (at the canteen or at-home with peers), reported a positive effect of providing choice on the vegetable consumption.

3.2. Long-term effects

Since we observed an increase in food intake when providing choice of one meal component, we may question whether this difference in intake would persist on a longer term. First, does it impact the total energy intake of the meal or of the day? Second, would this increase in food intake be persistent when exposed to repeated choices?

Eating more of one food can be counterbalanced with the following meal components during the same day (Almiron-Roig et al., 2013). In the study on vegetables, the dessert (apple puree) was served according to *ad libitum* conditions and the quantities consumed were measured. Even if we observed a positive choice effect on vegetable intake, we did not notice any difference in the quantities consumed of apple puree nor in the total energy intake of the meal across the four conditions. The lack of difference in the total energy intake throughout the meal is consistent with former studies that investigated the variety effect (Bucher et al., 2014; Meengs et al., 2012). Meengs et al. (2012) reported an increasing effect of providing a variety of vegetables with pasta on the vegetable quantities consumed and on the total meal, but reported no increase in the total energy intake. They assumed that vegetables dishes are low-energy foods which contribute to a lesser extent the total energy consumed during a meal: an increase of 50 g was not sufficient to impact total energy intake. Bucher et al. (2014) showed that the energy intake from vegetables increased when provided in a variety condition, while the total energy of the meal remained unchanged. Nevertheless, they reported that vegetables contributed to a larger extent the total energy intake in variety conditions (11 %) than in the no-variety condition (6 %), and therefore concluded that when offered a variety of vegetables, children favor a more balanced meal. To the best of our knowledge, no studies have evaluated whether providing choice and variety would affect satiety.

Previous studies have revealed the effect of providing choice and variety within one single meal, but we may question their impact when repeated during several meals. Two at-home studies explored the effect of repeated choice exposure on food acceptance and food intake. De Wild et al. (2015) showed that children investigated the impact of exposing 2 to 5 year-old children to choice between familiar vegetables 12 times. Children in the no-choice group were presented 1 vegetable in 12 exposures. Results showed greater intake of vegetables in the choice group than in the no-choice group. Zandstra et al. (2000) also reported that adults were less bored, displayed higher acceptance ratings and ate higher quantities when they had the opportunity to choose their meat sauce once a week for a 10-week period than adults served with the same meat sauce during the same period. Nevertheless, when

individuals have the opportunity to choose their food, they do not systematically vary their meals and choose the same item repeatedly (Kramer et al., 2001).

Numerous studies have evaluated the variety effect on a longer term (than within just one meal), but they more specifically investigated the impact of providing different foods at each meal. For instance, they compared a situation where individuals were provided a different food at each test meal to monotonous situations where individuals were served the same food (Meiselman et al., 2000; Zandstra et al., 2000).

3.3. Choice effect and age category

The present experiments were carried out on adults, and before generalizing the positive impact of providing choice on the pleasure to eat and the quantities consumed, it may be important to evaluate its impact on differently aged populations, such as children or elderly individuals.

Regarding children, it has been suggested that choice (not limited to food) has a greater impact on intrinsic motivation on children than on adults, probably because the lack of age-related opportunities for children to make choices has a greater impact once they do have the opportunity (Patall et al., 2008). While no studies have compared the size of the choice effect on food behavior, recent work confirms that offering food choice to children, even at 4 years old, may positively influence their liking regarding the eaten food and the quantities consumed (Altintzoglou et al., 2015; de Wild et al., 2015; Rohlf's Domínguez et al., 2013). These studies were carried out with the aim of investigating choice as a potential strategy to favor the consumption of healthy foods such as vegetable and fish. We previously assumed that restricting the opportunity for individuals to make choices among unhealthy foods could also be a strategy to limit the consumption of that food. Further studies on children based on unhealthy foods may be important to carry out in order to confirm this idea.

Improving the quality of the meal is an important challenge for nursing homes with catering. In France, malnutrition rates for individuals living in nursing homes range from 15 to 38 % (HAS, 2007). Improving the meal context has been identified as an effective strategy to increase the satisfaction with their meal and their food intake (Desai, Winter, Young, & Greenwood, 2007; Divert et al., 2015; Nijs et al., 2006). Organizing a food service that enables people to choose and serve their own food has been one contextual factor of interest. However, these studies did not set apart the impact of choice from other contextual factors, which prevent us from determining the specific effect of providing choice. It has been suggested that cognitive abilities decline with age and older adults would therefore be less likely to perform complex choices with an overload of information (Frey et al., 2015; Mata, 2007; Mata et al., 2011). Elderly individuals are also more likely to suffer from cognitive impairments—Alzheimer's disease, in particular that can lead to a loss of concentration during mealtime or problems identifying foods (Aselage & Amella, 2010). It follows that for those

individuals, making food choices might easily become a complex task, leading to a contrary effect of providing choice: a decline in satisfaction and in motivation to eat.

4. Conclusion

The present thesis aimed at investigating the impact of providing food choices on the pleasure to eat and the quantities consumed. The results confirm the theoretical framework of the Self Determination Theory as well as results from previous studies: offering an individual the opportunity to choose his or her food increases his or her liking regarding that food and, under certain conditions, the quantities consumed. The choice effect appears to be vulnerable to contextual factors, especially to the structure of the food product assortment. The experiments of the present thesis were carried out on adults under experimental conditions where the environment was especially controlled. **Figure 13** summarizes the factors that may influence food intake in real-life settings where individuals have the opportunity to make food choices.

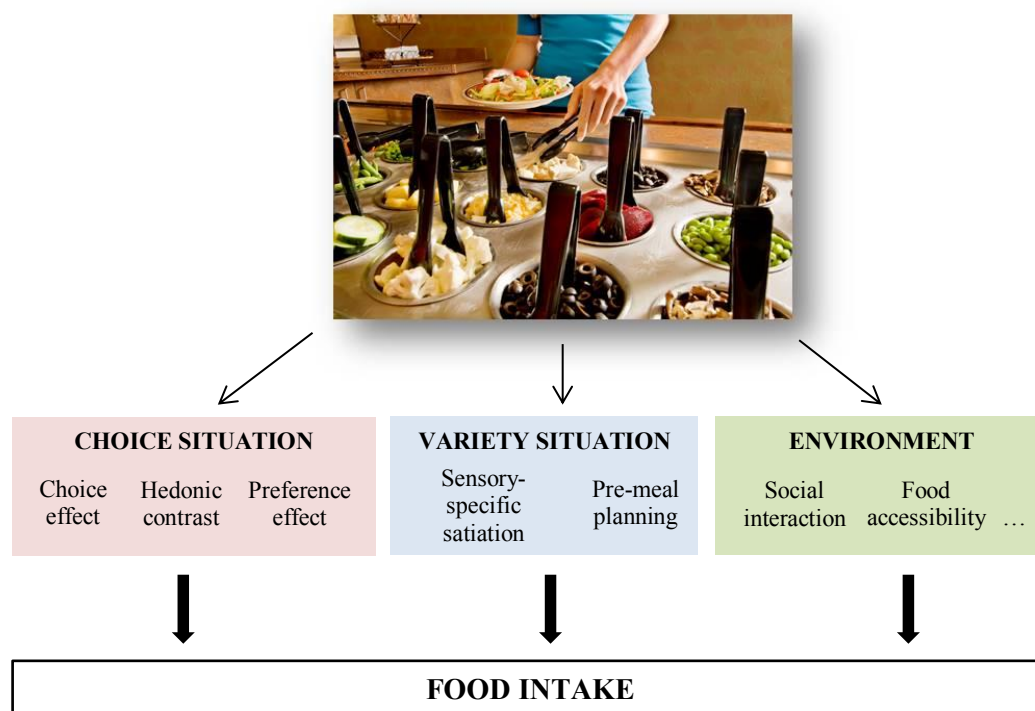


Figure 13. Effects that may influence food intake when making choice in natural settings

It especially highlights that choice may impact food intake through the three following mechanisms. One, the choice *per se* can impact the cognitive representation of a choice situation and enhance the motivation to consume higher quantities. Two, when making choice, individuals compare foods with varying appreciation that may decrease or increase the relative liking of each (hedonic contrast). We

assume that this change in relative pleasantness could impact the quantities consumed. Three, being offered several foods to choose from also gives the opportunity to find better-liked products, which could be associated with higher food intake. In natural environments, a variety effect might also occur since people might select several food items. Finally, it is noteworthy that environmental factors (for example social facilitation, food accessibility) could also play a role regarding the quantities consumed by individuals.

Appendix 1. Designing the sets of products

1. General objectives

The behavioral study on choice aimed at exploring the impact of two assortment characteristics:

- **Characteristic 1: the degree of similarities between the alternatives:** Does providing choice have the same effect when products are similar and when products are dissimilar?

Regarding this characteristic, we designed two sets of products. Set 1 included foods that varied in one sensory modality, while set 2 included foods that varied in several sensory modalities. Two experiments were carried out following the same paradigm: these products belonged to the same category, namely, dessert.

- **Characteristic 2: the level of pleasantness of the alternatives:** Does providing choice have the same effect when individuals have to choose from among pleasant or unpleasant alternatives?

Regarding this characteristic, each set of products should elicit contrasting hedonic ratings: people could encounter pleasant or unpleasant products. We considered pleasant products as those rated between 6 and 9 on the hedonic scale and unpleasant products those rated between 1 and 4 on the hedonic scale.

Subsequently, each set of desserts had to comply with common criteria:

- **Visual appearance:** To ensure that participants felt they had a choice between products without tasting, products had to appear visually different.
- **Similar liking:** in order to assess the effective impact of choice on food liking and food intake, individuals were provided choice between equally-liked alternatives. These experimental criteria prevented a preference effect when providing choice due to the opportunity of finding a more-appreciated alternative. We had to identify at least 3 products (pleasant or unpleasant) that differed by no more than 2 points on the hedonic scale.
- **Similar energy content:** in both behavioral experiments, we evaluated the impact of providing choice on food intake. In order to compare food intake between the choice and no-choice situations, even if the consumed products were not the same, products had to have similar energy content.

Table 4 sums up the criteria with which each set of dessert had to comply.

Table 4. Specific and common criteria for designing each set of products

	Set 1	Set 2
Specific characteristics	Products varying in one sensory modality	Products varying in several sensory modalities
Common characteristics (within each set)	The products should be visually different The difference in energy content between products should not exceed 20 kcal/100 g The products should elicit contrasting hedonic responses with products equally appreciated and products equally less appreciated.	

Then, we designed two sets of products: 1) a set of apple purees varying in texture and 2) a set of desserts from different categories, varying in texture, color, taste, a selection that reflected an assortment that individuals may encounter in a self-service context. The following sections present the methodologies used for designing these two sets of products, which required different strategies.

2. Designing the set of apple purees

2.1. General method

Apple purees were used as a food model in the study as they are common and largely consumed in France as a dessert, snack and even as a side dish. In the market, apple purees are offered with a high diversity of textures, from very smooth apple puree in flasks to products with chunks imitating “homemade” apple puree. It has been shown that consistency and graininess were the most important sensory attributes to describe the texture of market-sourced fruit purees (Colin-Henrion, Mehinagic, Patron, & Jourjon, 2009; Tarea, Cuvelier, & Sieffermann, 2007). Previous studies have also investigated the relationship between structural parameters and sensory perception of apple puree textures. Espinosa-Muñoz, Symoneaux, Renard, Biau and Cuvelier (2012) identified particle size and pulp content as key structural properties to master the graininess and consistency of apple purees. We accordingly designed a set of apple purees by modifying an initial apple puree (to assure similar energy content) through three structural parameters: particle size, pulp content and addition of apple fragments.

The design of the apple puree sets followed 2 steps, as described in **Figure 14**. The first step consisted of the development of the purees at a laboratory-scale production. A flash profile allowed us to characterize their texture and to monitor whether they were perceived differently according to the sensory criteria. The hedonic test evaluated whether the apple purees met the hedonic criteria. For the

needs of the behavioral study, the process of formulation was created during a pilot and later up-scaled to enable production of larger quantities. Sensory tests were carried out to monitor the replication of the apple puree sets at a larger scale.

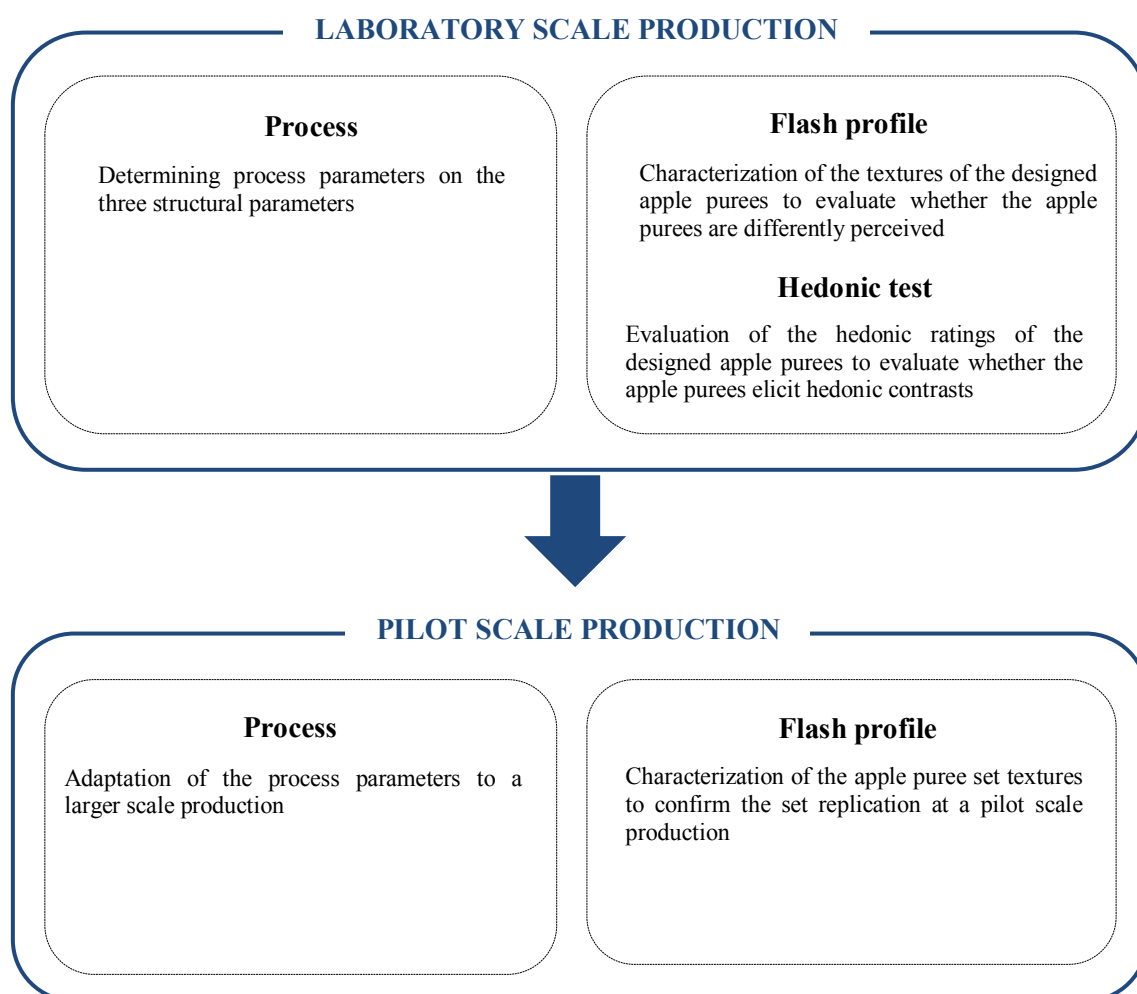


Figure 14. Overview of the methodology used to design the set of apple purees

2.2. Laboratory-scale production

2.2.1. Formulation process at a laboratory-scale production

A set of 12 apple purees that varied in texture was designed by modifying an initial apple puree through three structural parameters: particle size, pulp content and addition of apple fragments. The initial apple puree contained apple fragments that were also used in the designed apple purees with apple fragments. Designing a set of apple purees by modifying the structure of an initial apple puree allowed us to create a set of products with similar energy content. **Figure 15** provides a general overview of the apple puree design according to the three structural parameters.

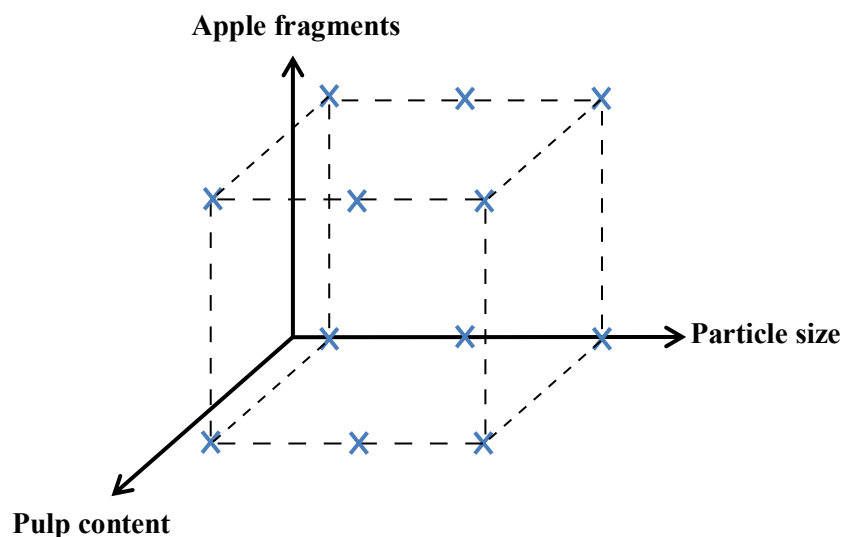


Figure 15. Three structural parameters (particle size, pulp content and the addition of apple fragments) modified to design the set of 12 apple purees (represented by crosses) at a laboratory scale

The process used for designing this set of apple purees is detailed in **Figure 16**. The initial apple puree (Pomme Nature en Morceaux, Sans Sucres Ajoutés, Andros®) was ground according to 3 levels, creating 3 products: Low (L), Medium (M), Highly (H) by using a grinder Grindomix GM 200 Retsch (batch of 400g). Three more products were then designed by increasing the pulp content. After a concentration step (2 hours at 5000 g; Centrifugeuse 3-18K, Sigma, Fisher Bioblock Scientific) the collected pulp was added to the L, M and H apple purees to create LC, MC, HC, respectively. Apple fragments were then recovered from the initial apple puree and introduced to the 6 previous apple purees at 50 % in weight to design LF, MF, HF, LCF, MCF, HCF.

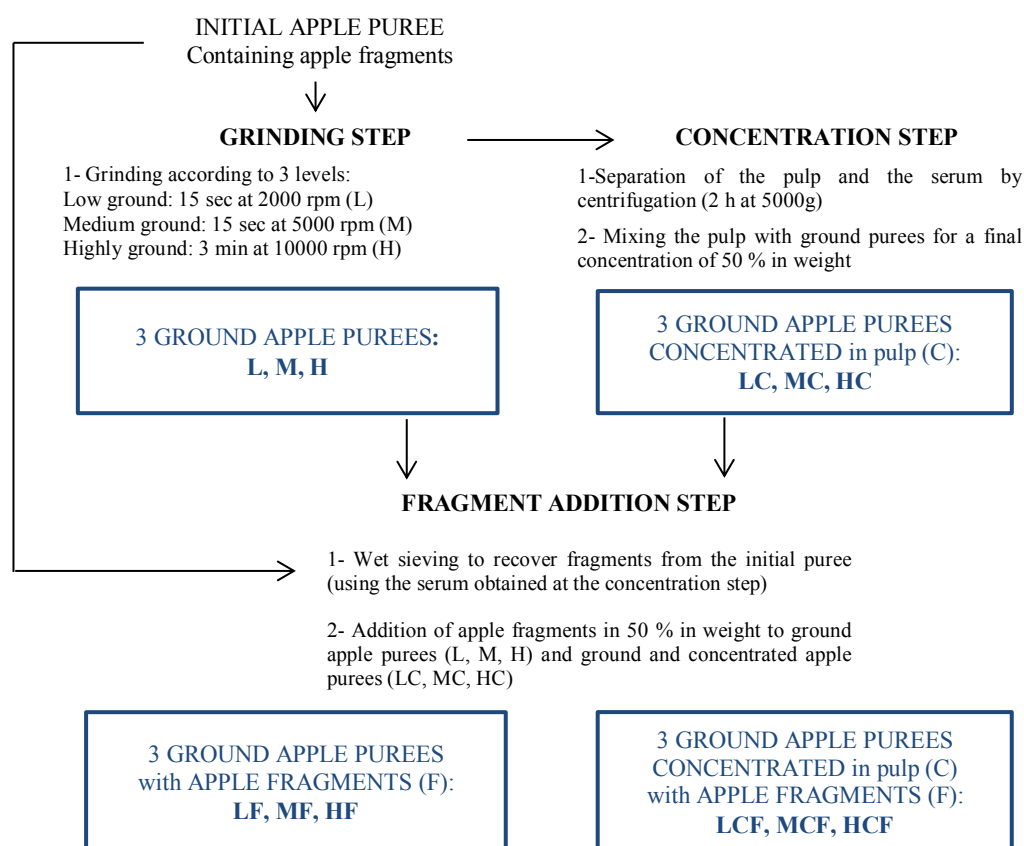


Figure 16. Formulation process of the 12 apple purees at a laboratory scale

2.2.2. Texture characterization through a flash profile

The characterization of the texture of the set of designed apple purees was carried out through a flash profile. Five adults from the Food Science Department in AgroParisTech (1 avenue des Olympiades, 91744 Massy, France) were recruited to participate in the flash profile. L was used as a duplicate sample to evaluate rating consistency by the judges. The 13 apple purees were randomly identified with letters from A to M. They were provided at ambient temperature in 50 g portions. The flash profile was conducted in individual sensory booths at room temperature. Before starting the session, the experimenter explained the procedure to each expert. They were told that the goal was to characterize the perceived sensory differences between the 13 apple purees. The set of products were simultaneously offered with 13 spoons and water. Experts were asked to focus on every aspect of the products by observing, manipulating, and tasting. They had to report each attribute on an individual answer sheet previously provided, and had to rank the samples on a visual analog scale that they anchored themselves. They were allowed to rank products equally but were requested to circle them to avoid any confusion during the results analysis. For each attribute, they also had to specify the definition or the methodology used. They received no limitations concerning the number of attributes and the time they had. During the session, experts had the possibility to rinse their mouths when they

wished, and also to take a break of a few minutes if necessary. The data analysis for the flash profile was performed using a Generalized Procustes Analysis (GPA)(Gower method) with XLSTAT (version 2014.2.07, Addinsoft, New York, NY).

Each expert generated between 5 and 13 attributes, for a total of 45. Fifteen attributes (33.3 %) were generated when looking at apple purees, 11 attributes (24.4 %) when using a spoon, and 19 (42.2 %) when tasting. A total of 42 attributes were related to the texture (93.3 %). The map of products and the circle of correlations that resulted from the flash profile are presented in **Figure 17**.

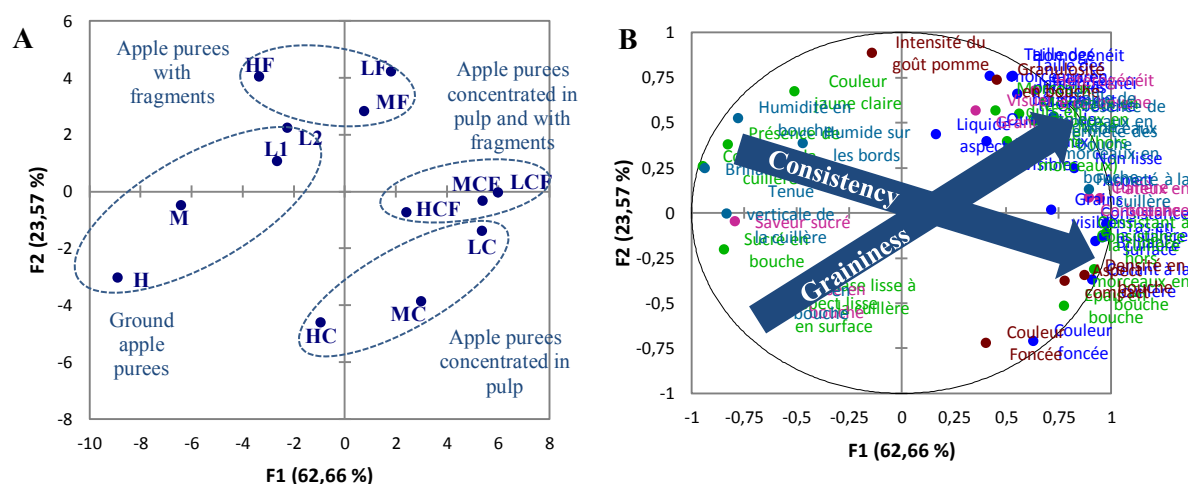


Figure 17. Flash profile of the apple purees designed at a laboratory scale: map of the products (A) and circle of correlations (B)

The two main components, F1 and F2, that result from the GPA explain 86.2 % of the total variance with the first component F1 being 62.7 % and F2 being 23.6 %. The map of products shows a proximity between positions L1 and L2 (duplicated products), confirming the rating consistency by the judges. The map also reveals that concentrated apple purees are in the bottom right compared to their equivalent non-concentrated apple purees. Highly ground purees are located to the bottom left compared to less ground purees. Purees with apple fragments are in the upper right compared to their equivalent without-fragment apple purees. The circle of correlations highlights two principal orthogonal dimensions: graininess and consistency. The graininess dimension may be associated with particle size and apple fragments, and consistency with pulp content or concentration.

2.2.3. Hedonic test

Thirty-four adults were recruited to participate in the hedonic test. The 12 products were identified with randomly assigned 3-figure codes. Around 30 g of each apple puree was served in small bowls. Products were presented according to a sequential monadic procedure in the order determined by a

Williams Latin square design. The participants tasted each product and evaluated their liking for the product on a 10-point hedonic scale ranging from “I do not like it at all” (0) to “I like it very much” (10).

Results, expressed in terms of mean liking and the ratio SEM/mean, are represented in **Figure 18**. The ratio SEM/mean combines both the information regarding the variability and the mean of each apple puree: a high SEM stands for high variability and, associated with a low mean leads to a high SEM/mean ratio value. The less-liked product (H) was on average rated 3.9 (SEM=0.3) while the most-liked product (L) was on average rated 6.8 (SEM=0.3). The H and HC apple purees displayed the lowest mean but highest variability of hedonic ratings.

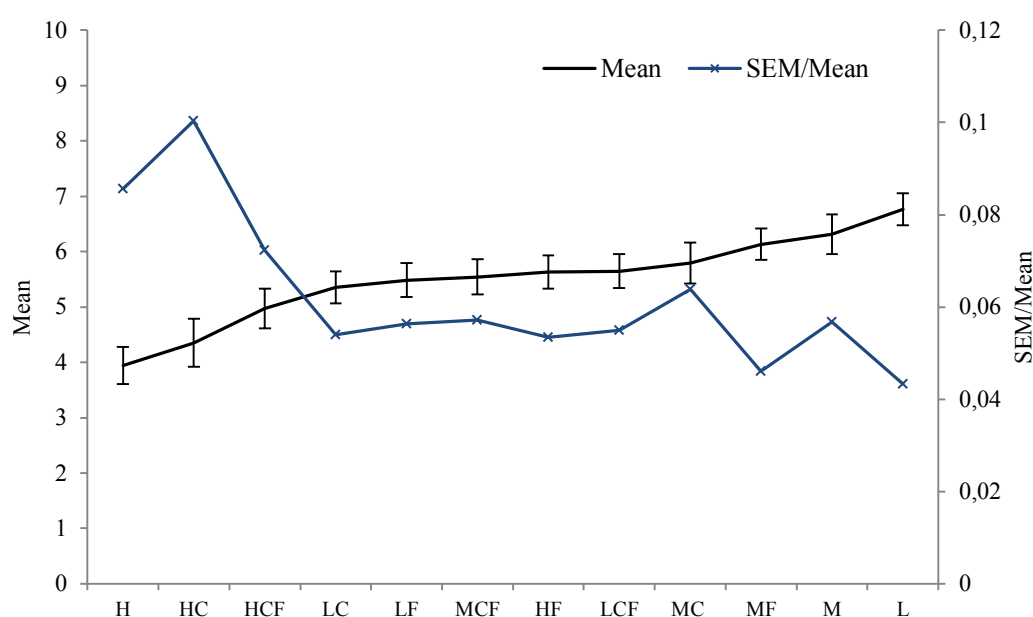


Figure 18. Hedonic ratings: mean and SEM/ratio for the apple purees designed at a laboratory scale (Means are expressed with their SEM)

Results confirmed that all the apple purees elicited contrasted hedonic responses: the minimum and maximum hedonic ratings for each participant were 2.6 (SEM=0.2) and 8.2 (SEM=0.2). Furthermore, all subjects had at least 3 pleasant (i.e. scored between 6 and 9) or 3 unpleasant (i.e. scored between 1 and 4) apple purees with similar liking (i.e. that differed by no more than 2 points on the hedonic scale): 31 subjects (91 %) had at least 3 pleasant products and 24 subjects (71 %) had at least 3 unpleasant products.

2.3. Pilot-scale production

2.3.1. Formulation process at a pilot-scale production

The behavioral study on choice and no-choice required the processing of almost 1 ton of initial apple puree. It was then necessary to optimize the process used at the laboratory. We used a grinder with higher capacity and optimized the concentration step by reducing the time of centrifugation. However, the grinder used at the pilot-scale did not enable us to reproduce all the desired textures of apple purees because the speed was not high enough (especially the highly ground purees (H)), which were identified in the preliminary hedonic test as textures of interest regarding hedonic criteria. When tasted, H was liquid and smooth: small particle size distribution tends to reduce the viscosity of the product. In order to reduce the viscosity, we diluted the H texture obtained at the maximum grinding level. Another texture of interest was HC, which was as dense as a fruit pastry filling. We then increased pulp content for that texture. **Figure 19** presents an overview of apple puree design through the three structural parameters at the pilot scale.

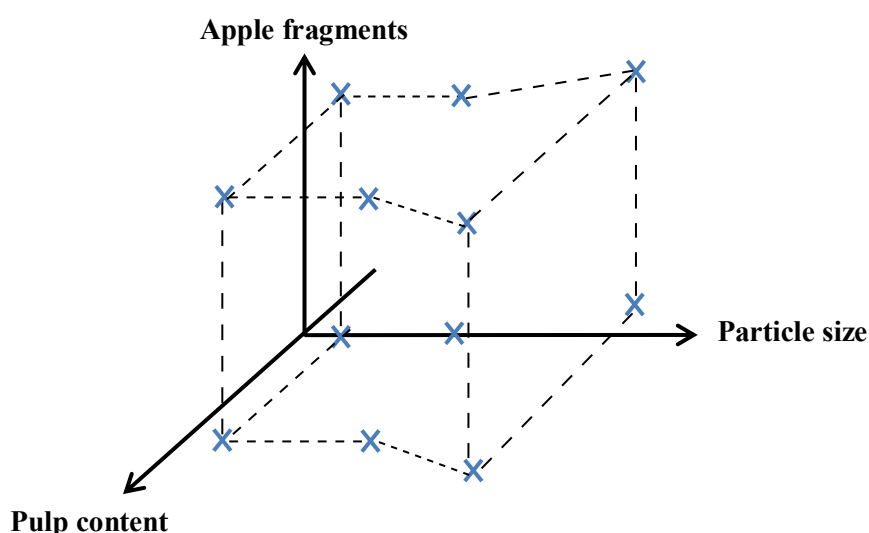


Figure 19. Structural parameters (particle size, pulp content and the addition of apple fragments) modified for designing the set of 12 apple purees at the pilot scale (represented by crosses)

The process used to design this set of apple purees is detailed in **Figure 20**. The initial apple puree was ground according to 3 levels, creating 3 products: Low (L), Medium (M), Highly (H). H was not used for the test but was diluted with apple serum (issued from the centrifugation) to create Hd, a liquid and smooth texture. Three more products were then designed by increasing the pulp content. After a concentration step (20 min at 5500 g; Centrifugeuse 3-18K, Sigma, Fisher Bioblock Scientific) the pulp collected was added to the L, M and H apple purees to create, respectively, LC, MC, HC. Apple

fragments were then recovered from the initial apple puree and introduced to the 6 previous apple purees at 50 % in weight to design LF, MF, HdF, LCF, MCF, and HCF.

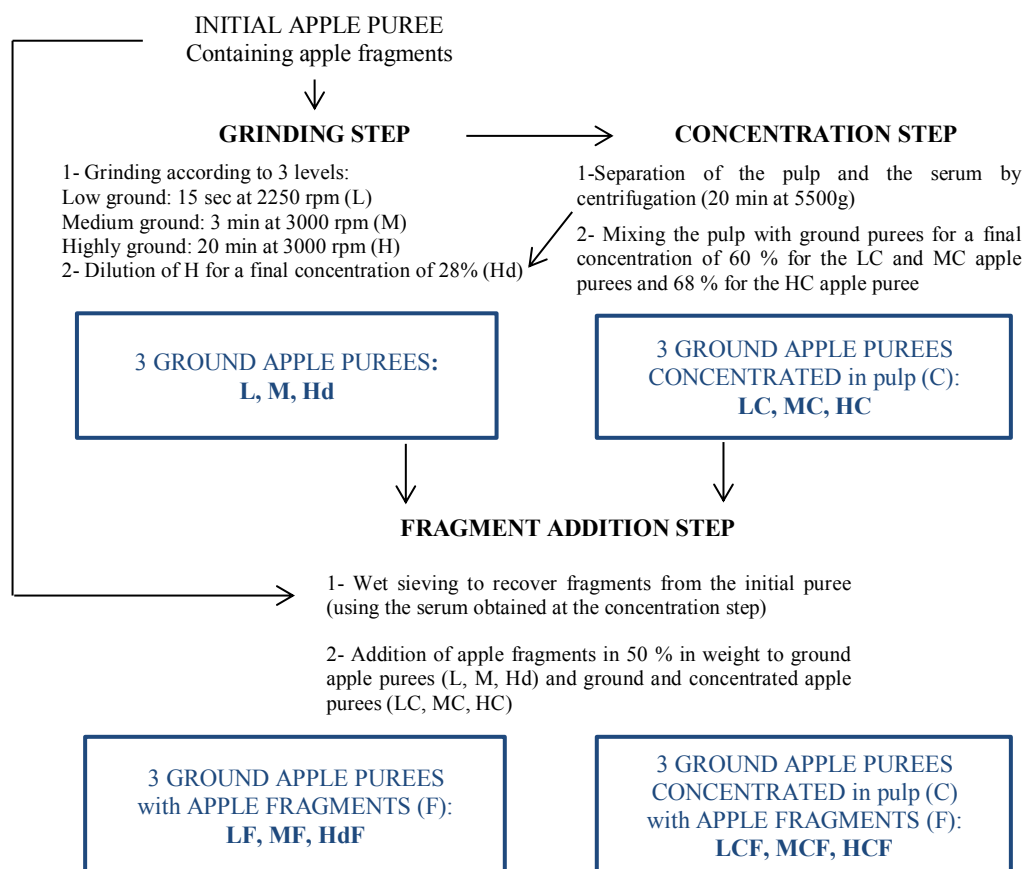


Figure 20. Process of formulation for the 12 apple purees at a pilot-scale

The apple purees were vacuum packed, stored at -20°C, defrosted in a fridge (4°C) the day before the experiment and stored at room temperature 3 hours before the flash profile and the hedonic test.

2.3.2. Texture characterization through a flash profile

A flash profile was conducted on this final set of apple purees. Ten adults from the Food Science Department in AgroParisTech (1 avenue des Olympiades, 91744 Massy, France) (3 men and 7 women) were recruited to participate in the flash profile. All sets of designed apple purees were proposed at the test. M was used as a duplicate sample to evaluate rating consistency by the judges. The initial apple puree was also included in the test. The 14 apple purees were randomly identified with letters from A to N. They were provided at ambient temperature in 50 g portions. The procedure was identical to the set of apple purees designed at the laboratory-scale.

The flash profile sessions lasted between 30 and 90 min. Six attributes were excluded from the analysis because mistakes prevented data analysis. Each expert generated between 3 and 12 attributes

(for a total of 74). Twenty seven attributes (36.5 %) were generated when looking at apple purees, 27 attributes (36.5 %) when tasting them, 18 attributes (24 %) when using a spoon and 2 (3 %) when smelling. A total of 66 attributes were related to the texture (89.2 %).

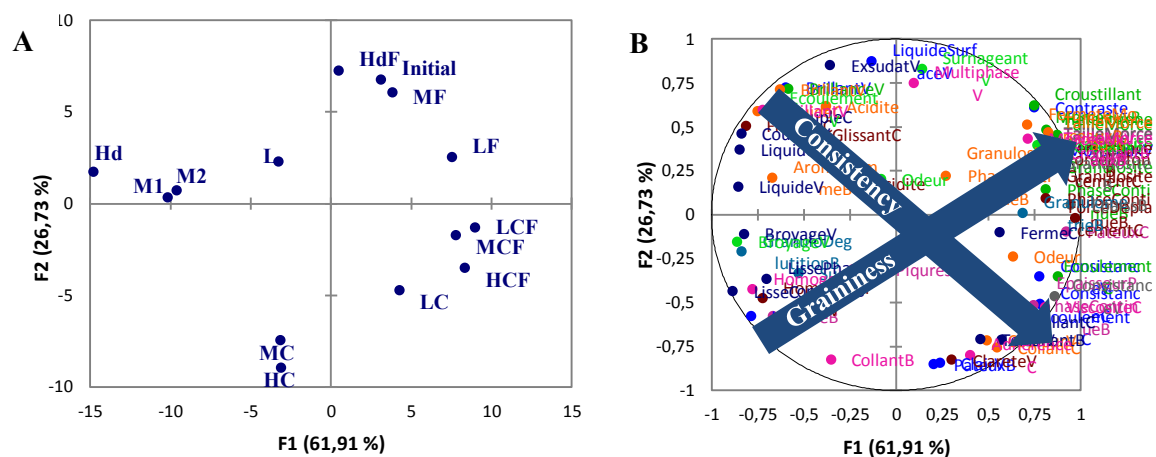


Figure 21. Flash profile on the apple purees designed at a pilot-scale: map of the products (A) and circle of correlations (B)

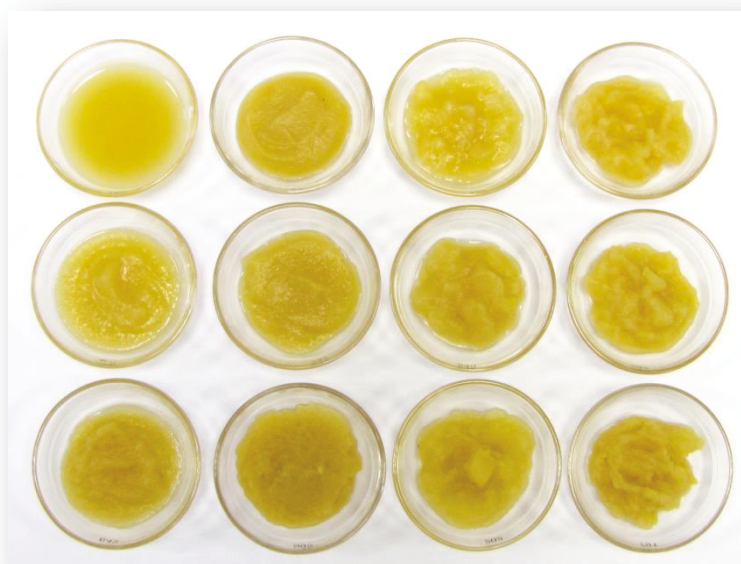
Figure 21 displays the map of products and the circle of correlations that resulted from the flash profile. The total variance (88.6 %), the variance of F1 and F2 axis (61.9 % and 26.7 %, respectively), the direction of the graininess and consistency dimensions (represented in the circle of correlations), and the positions of the apple purees represented on the map of the products are similar to results of the flash profile carried out on apple purees processed at the laboratory-scale.

2.4. Final set of apple purees

Results flash profiles allowed us to conclude that individuals were able to visually distinguish the apple purees (as participants generated numerous visual attributes), and that these apple purees mainly varied in texture (as participants reported around 90 % of attributes being relative to the texture). Hedonic tests also confirmed that the set of apple purees complied with the hedonic criteria, in particular because they generated contrasted hedonic ratings. The nutritional composition of the apple purees was evaluated by the ISHA (Institut Scientifique d'Hygiène et d'Analyse, Champlan) and results confirmed that the apple purees displayed very similar energy content (**Table 5**). The final set of 12 apple purees is presented in **Figure 22**.

Table 5. Nutritional composition of the final set of 12 apple purees

Apple purees	Energy (kcal/100g)	Protein (g/100g)	Carbohydrates (g/100g)	Fat (g/100g)
L	56.0	0.3	13.2	0.3
LC	58.9	0.4	13.3	0.5
LF	55.6	0.4	13.0	0.2
LCF	57.6	0.4	13.1	0.4
M	57.0	0.4	12.8	0.5
MC	57.8	0.4	13.5	0.2
MF	57.0	0.3	13.0	0.4
MCF	57.7	0.4	13.4	0.3
Hd	54.0	0.3	12.3	0.4
HC	58.1	0.7	13.3	0.3
HdF	56.2	0.3	12.9	0.4
HCF	57.2	0.3	13.4	0.3

**Figure 22.** Final set of 12 apple purees varying in texture

3. Designing the dessert set

3.1. General method

A second set of 12 desserts was designed where products had to vary in several sensory modalities (such as color, texture and taste) and also had to comply with the criteria described in the general objectives. For that purpose, a different methodology than that used for the set of apple purees was

employed since these desserts were products available in the French market. The methodology is described in **Figure 23** and includes two steps. The first step aimed pre-selecting a first set of desserts through an on-line questionnaire and a benchmark carried out in French supermarkets. The second step consisted of consumer tests carried out on the desserts pre-selected in step 1 to retain a final set of 12 desserts that complied with the sensory and hedonic criteria.

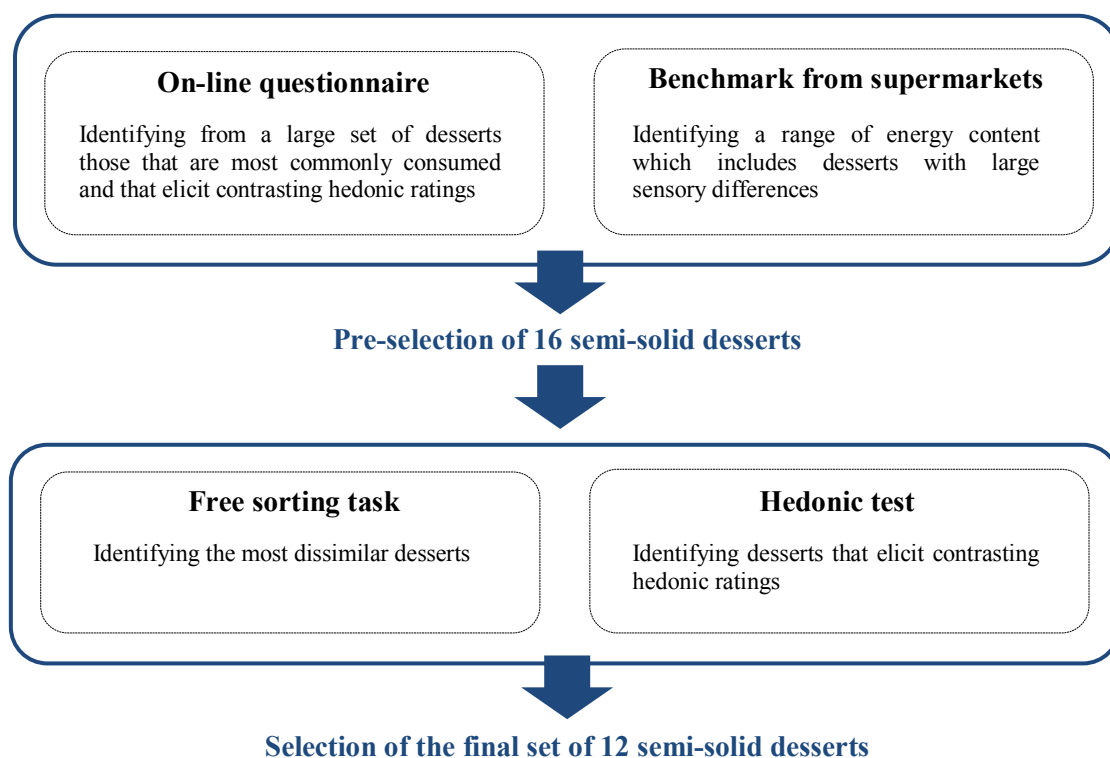


Figure 23. Overview of the methodology used for the selection of the dessert set

3.2. Pre-selection of the dessert set

3.2.1. On-line questionnaire

An on-line questionnaire on Survey Monkey was carried on 327 subjects. Subjects rated their liking of 22 desserts (dairy products, puddings, fruits with syrup, fruit purees and cakes) that may be offered in self-service situations according to a 9-point hedonic scale (anchored “Extremely pleasant”- “Extremely unpleasant”). Individuals also indicated whether they had already tasted each dessert.

Results of the hedonic ratings are displayed in **Figure 24**. The least-appreciated dessert (cake with fruits) had a mean liking-score of 4.3 (SEM=0.1), while the most appreciated dessert (apple puree) had a mean liking score of 6.9 (SEM=0.1). A hierarchical cluster analysis was carried out on the raw liking scores and revealed three patterns of liking profiles (group of consumers 1, 2 and 3 in **Figure 24**). These three profiles of liking allowed us to identify desserts that generated contrasting hedonic ratings

(such as creamy semolina puddings, creamy rice puddings, and to a lesser extent coconut-flavored yogurt, vanilla dessert cream and cottage cheese) and desserts that displayed consensual liking scores (such as plain yogurts and apple puree).

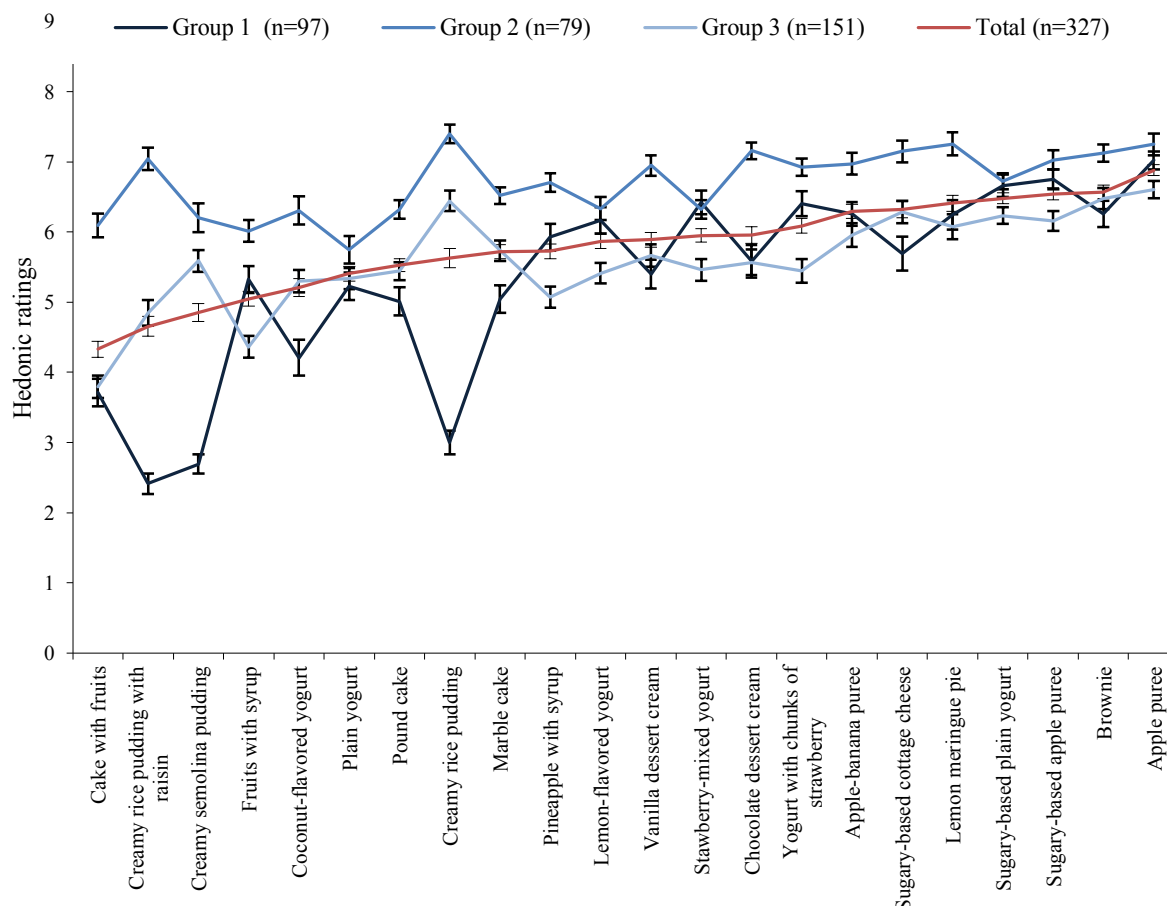


Figure 24. On-line questionnaire: hedonic ratings for the 22 desserts for all consumers (total) and for each group of consumers (1, 2 and 3) resulting from the hierarchical cluster analysis

3.2.2. Benchmark from supermarkets

The benchmark aimed at pre-selecting a dessert set that varied in different sensory modalities within a small scale of energy content (the difference should not exceed more than 20 kcal/100 g). To design the final dessert set, we selected only semi-solid desserts as firstly, it enabled a similar presentation to the apple purees and secondly, because the cakes had a higher energy content that prevented us from selecting enough products within an interval of 20 kcal/100 g of difference. Forty-one semi-solid desserts were then bought in supermarkets around Paris. Desserts whose textures were modified by only manipulating when serving (ex: coconut-flavored yogurt) were excluded from the pre-selection. Within an interval of 90-120 kcal/100 g, we could find numerous semi-solid desserts from different

categories of desserts (dessert creams, puddings, fruit purees and dairy products), and in particular, desserts that were highlighted by the on-line questionnaire according to hedonic criteria (such as creamy rice puddings, creamy semolina puddings, vanilla dessert cream, plain yogurts and apple purees). Within each category of products, we selected those that varied in flavor and texture. For example, the three dessert creams did not only vary in flavor but also displayed different textures. Sixteen semi-solid desserts were finally pre-selected and are represented in **Table 6**.

Table 6. Set of 16 semi-solid desserts pre-selected after the on-line questionnaire and the benchmark from supermarkets

Desserts	Fruits	Dairy products
Creamy rice pudding-Mont Blanc	Apple puree-Andros	Plain yogurt-M&A
Creamy semolina pudding-Auchan	Rhubarb puree-Bonne Maman	Cottage cheese-Malo
Pistachio dessert cream-Danette	Apricot puree-Andros	Cottage cheese-Cora
Vanilla dessert cream-Cora	Raspberry puree-Andros	Vanilla yogurt-Vrai
Chocolate dessert cream-Montblanc		Raspberry-blueberry yogurt-M&A
		Blueberry yogurt-Danone
		Prune yogurt-Activia

3.3. Selection of the final dessert set through consumer tests

A hedonic test and a free sorting task were then carried out on the pre-selected 16 desserts to retain a final set of 12 desserts that comply with the hedonic and sensory criteria.

Sixty four students were recruited and served 30 g of each product using a sequential monadic procedure. The products were presented in the order determined by a Williams Latin square design. The participants tasted each product and evaluated their liking for the product on a 10-point hedonic scale ranging from “I do not like it at all” (0) to “I like it very much” (10). Participants were requested to rinse their mouths with plain water between each tasting. At the end of the hedonic test, 33 participants were asked to carry out a free sorting task. They were simultaneously presented the sixteen samples and asked to sort the samples into groups based on perceived similarities. They were allowed to taste the products several times and to make as many groups as they wanted. The data analysis for the free sorting task was performed using a Multidimensional Scale with XLSTAT (version 2014.2.07, Addinsoft, New York, NY).

Results of the free sorting task and the hedonic test are displayed in **Figure 25** and **Figure 26**, respectively. **Figure 25** is a 2-dimensional map of the products, which results from the multidimensional scale analysis. Despite Kruskal’s stress (0.23) displaying a relative high value (higher than 0.20), indicating a relative poor assessment of fit with this MDS solution, this

configuration enabled us to identify four groups in which desserts were perceived as the most similar. Indeed, the table of similarities supports this conclusion since the two cottage cheeses were classified in the same group 33 times, plain yogurt and cottage cheeses 31 times (Group 1), rhubarb puree and apple puree 30 times (Group 2), raspberry puree and apricot purees 28 times (Group 3) and blueberry yogurt and raspberry-blueberry yogurt 29 times (Group 4).

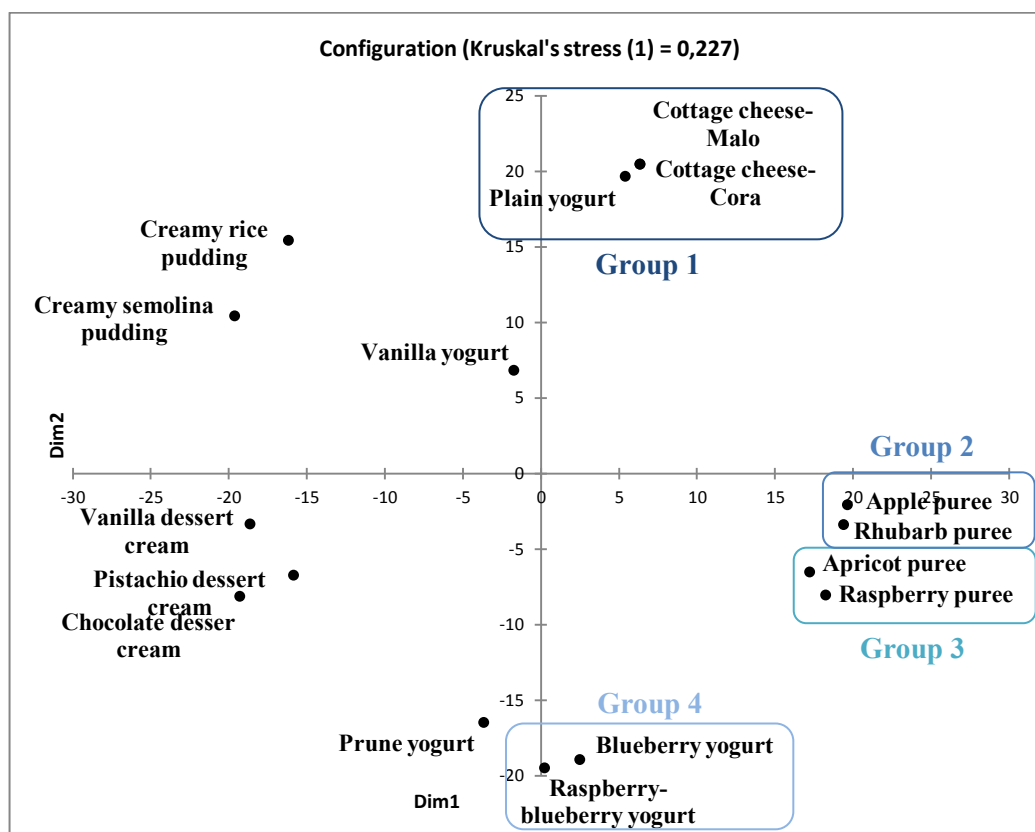


Figure 25. Two-dimensional map of the products resulting from the analysis of the free sorting task using Multidimensional Scale (Kruskal' stress)

With the aim of maximizing the sensory differences between the products of the final set, the four desserts that had to be eliminated were four products from these groups.

Results of the hedonic test are displayed in **Figure 26** and showed that the least-liked product (Cottage cheese-Cora) was on average rated 4.02 (SEM=0.3) and the most liked product (Blueberry yogurt) was on average rated 7.06 (SEM=0.2). The hedonic criteria for the design of this dessert set posit that within this set, individuals could find unpleasant and pleasant products (rated between 1 and 4 and 6 and 9 on the 10-point hedonic scale, respectively). Since results of the hedonic tests showed that these desserts were on average well appreciated, the selection of the products in the four groups identified above focused on products that were less appreciated or elicited higher hedonic contrasts. As for the selection of apple purees, we used the SEM/mean ratio, which combines both the information

regarding the variability and the mean of each apple puree (a high SEM stands for a high variability and, associated with a low mean, leads to a high SEM/mean ratio value). In each group, we kept desserts with lower mean ratings and also higher SEM/mean ratio values.

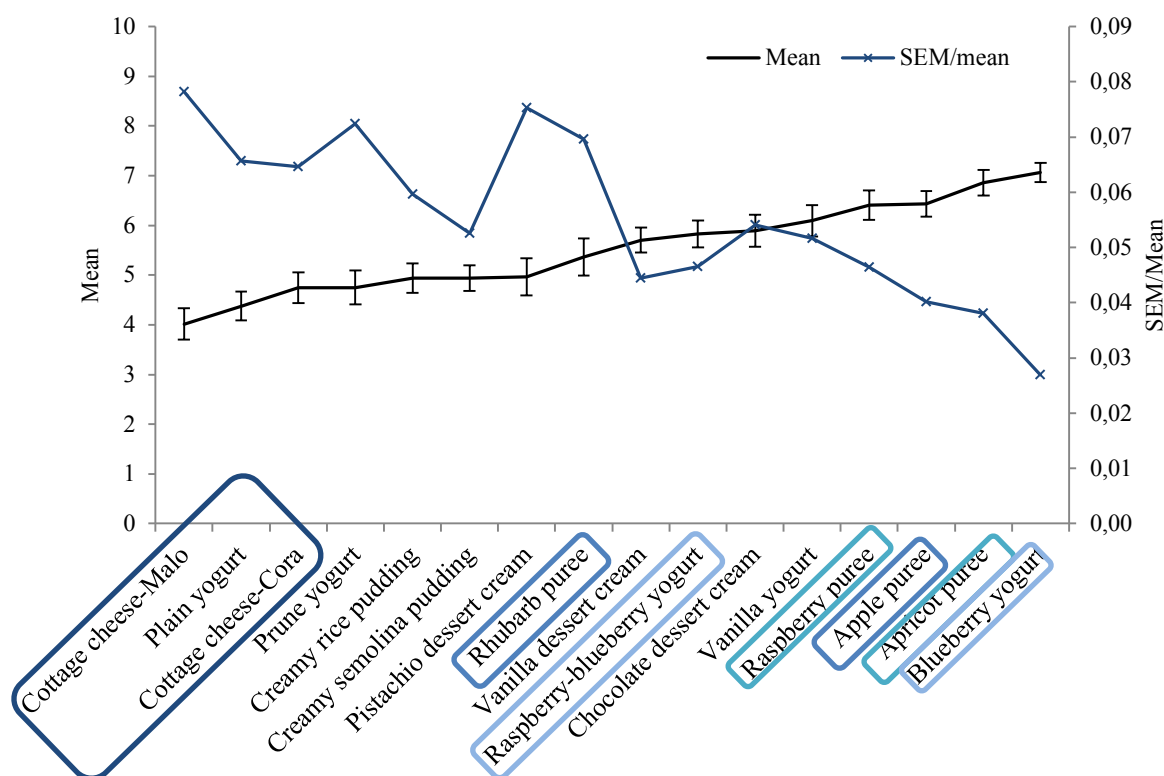


Figure 26. Hedonic ratings: means (represented with their standard error) and SEM/mean ratio for the set of desserts (products circled with similar color belonged to the same group previously identified by the free sorting task (see Figure 25))

In Group 1, the cottage cheese (Malo) was kept as it displayed the lowest mean hedonic ratings (4.02) and the highest SEM/mean ratio (0.08) compared to plain yogurt and cottage cheese (Cora). In Group 2, while apple puree had a higher hedonic rating (6.4) and a lower SEM/mean ratio (0.04) than the rhubarb puree, we kept both products as apple puree was the product of interest in the first set of products and rhubarb puree was a dessert that elicited a higher hedonic contrast (higher SEM/mean ratio value; 0.07). In Group 3, raspberry puree and apricot puree had similar mean hedonic ratings (6.4 and 6.9, respectively): the raspberry puree was used as it had a slightly higher SEM/mean ratio value than apricot puree (0.05 and 0.04, respectively). In Group 4, the raspberry-blueberry yogurt was used since it had a lower mean hedonic rating (5.8) and had a higher ratio (0.05) than blueberry yogurt.

To conclude, plain yogurt, cottage cheese (Cora), apricot puree and blueberry yogurt were not kept and used. According to this selection, 63 subjects (of the total of 64) had at least 3 unpleasant (i.e. scored between 1 and 4) or 3 pleasant (i.e. scored between 6 and 9) desserts with similar liking (i.e.

that differed by no more than 2 points on the hedonic scale): 42 subjects (66 %) had at least 3 unpleasant products and 62 subjects (97 %) had at least 3 pleasant products.

3.4. Final dessert set

The final set of 12 semi-solid desserts included 5 desserts, 3 fruit desserts and 4 dairy products that complied with the hedonic criteria and varied according to several sensory modalities (taste, color, texture) as shown in **Figure 27**. The energy content was evaluated by the ISHA (Institut Scientifique d'Hygiène et d'Analyse, Champlan) and confirmed that desserts did not differ by more than 20 kcal/100 g (**Table 7**).



Figure 27. Final set of desserts

Table 7. Nutritional composition of the final set of 12 desserts

	Energy (kcal/100g)	Protein (g/100g)	Carbohydrates (g/100g)	Fat (g/100g)
Pistachio dessert cream	109.1	2.8	18.0	2.9
Chocolate dessert cream	117.0	3.3	15.3	4.3
Vanilla dessert cream	114.9	2.8	19.1	3.0
Creamy rice pudding	113.3	2.4	21.5	2.0
Creamy semolina pudding	105.0	3.5	15.9	3.0
Apple puree	103.7	0.3	25.6	<0.1
Raspberry puree	101.6	0.7	24.7	<0.1
Rhubarb puree	107.8	0.8	26.1	<0.1
Vanilla yogurt	99.1	3.3	15.2	2.8
Raspberry-blueberry yogurt	100.1	2.3	10.9	5.2
Prune yogurt	100.0	3.4	14.4	3.2
Cottage cheese	103.9	5.9	4.6	6.9

Appendix 2. Résumé substantiel

1. Introduction générale

1.1. Contexte de la thèse

Actuellement, un individu fait face à de nombreux choix vis-à-vis de son alimentation au quotidien (évalués à plus de 200 selon Wansink et Sobal, 2007), et notamment lors du repas. Alors qu'à la maison, la décision du repas est souvent prise par la personne qui cuisine, la restauration collective s'organise davantage autour de modèle de type cafétéria ou buffet offrant aux consommateurs la possibilité de choisir le ou les aliments qu'ils souhaitent consommer.

Le programme DIDIT (Déterminants et Impacts de la Diète : Interactions et Transitions) est un programme de recherche mis en place par l'INRA (Institut National de la Recherche Agronomique), en 2012, ayant pour objectifs de 1) comprendre, modéliser et prédire les effets des déterminants du comportement alimentaire et 2) établir des relations entre les pratiques alimentaires et la santé pour évaluer l'impact de mesures d'interventions et fournir des recommandations de santé publique. Cette thèse s'inscrit dans le cadre d'un des projets de ce métaprogramme (PleasIn) et vise à apporter des éléments de connaissances sur l'effet du choix de ses aliments sur le plaisir de manger et la prise alimentaire.

Pour une meilleure compréhension des travaux de thèse présentés, la notion de choix alimentaire mérite d'être définie dès maintenant comme étant *l'opportunité donnée à un individu de sélectionner le ou les aliments qu'il souhaite consommer*.

1.2. Introduction bibliographique

1.2.1. Mécanismes des choix alimentaires et leurs effets sur les comportements alimentaires

Comprendre les effets des choix alimentaires nécessite dans un premier temps de s'intéresser au processus de prise de décision lié à l'alimentation. Les comportements alimentaires sont gouvernés par les choix relatifs à l'alimentation que nous réalisons au quotidien et résultent de nos expériences passées et d'influences liées notamment au contexte (contexte social, ressources disponibles) (Sobal & Bisogni, 2009).

Si de nombreux travaux ont cherché à modéliser les choix alimentaires, peu n'ont jusqu'à maintenant porté sur l'effet de ces choix sur les comportements alimentaires. Néanmoins, d'autres domaines de recherches tels que l'éducation ou la santé ont mis en évidence que le choix influençait positivement

les comportements ultérieurs (Cordova & Lepper, 1996; Iyengar & Lepper, 1999; Ng et al., 2012; Reeve et al., 2003). La théorie de l'auto-détermination développée par Deci et Ryan postule que chaque individu a trois besoins psychologiques essentiels que sont le besoin d'autonomie (sentir être à l'origine d'une action), le besoin de compétence (se sentir efficace) et le besoin d'affiliation (se sentir en relation avec les autres) (Deci & Ryan, 2002). Selon cette même théorie, la satisfaction de ces trois besoins psychologiques mène à une augmentation de la motivation intrinsèque à réaliser une action (i.e réaliser une action pour son auto-satisfaction, en opposition à la motivation extrinsèque définie comme le désir de réaliser une action pour une récompense extérieure). Le choix permet donc à un individu de satisfaire ses besoins d'autonomie et de compétence et augmente ainsi la motivation intrinsèque à réaliser une action, associée à d'autres effets tels que la satisfaction ou l'amélioration des performances (Ellen J. Langer, 1975; Patall et al., 2008; Zuckerman et al., 1978).

La théorie de l'auto-détermination nous amène donc à émettre l'hypothèse que donner à un individu l'opportunité de choisir l'aliment qu'il souhaite consommer augmenterait le plaisir de consommer cet aliment et la prise alimentaire associée. Il est également important de noter que de nombreuses recherches ont montré que le niveau d'appréciation d'un aliment influençait les quantités consommées (Bolhuis et al., 2012; De Graaf et al., 1999; Sørensen et al., 2003; Yeomans, 1996).

.Donner à un individu l'opportunité de choisir ses aliments a ainsi été étudié comme l'un des leviers d'action permettant d'améliorer l'acceptabilité et la consommation de fruits et légumes chez les enfants (Hendy, 1999; Hendy et al., 2005; Perry et al., 2004; Zeinstra, Koelen, et al., 2010) mais également d'améliorer l'expérience de repas des personnes âgées sensibles à des problèmes de dénutrition (Kremer et al., 2012; Nijs et al., 2006; Remsburg et al., 2001). Néanmoins, ces études ont évalué plus généralement des stratégies incluant le choix mais associé à d'autres leviers d'action (tels que l'interaction sociale ou la qualité du lieu de prise de repas) et ne nous permettent donc pas de conclure sur l'effet du choix pris isolément.

De récents travaux ont néanmoins étudié l'impact du choix sur l'appréciation des aliments et la prise alimentaire en le dissociant d'autres variables de contexte. Il a été montré qu'en situation de choix, des adultes pouvaient attribuer des notes d'appréciation plus importantes qu'en situation de non-choix pour certains aliments (King et al., 2008, 2004). De même chez les enfants, Altintzoglou et al. (2015) ont montré un effet positif du choix sur l'appréciation de poissons par rapport à du non choix alors que Zeinstra, Renes, et al. (2010) ont montré que laisser la possibilité de choisir ses légumes à un enfant au restaurant n'influencait pas l'appréciation des légumes consommés. Concernant la prise alimentaire, deux études de protocole semblable menées chez des enfants ayant le choix de consommer les légumes souhaités ont également montré des résultats divergents : Zeinstra, Renes, et al. (2010) n'ont montré aucun effet sur la prise alimentaire alors que Rohlf's Domínguez et al. (2013) ont mis en évidence une augmentation de la prise alimentaire de légumes lorsque les enfants avaient la possibilité de choisir.

Ces trois derniers travaux menés chez les enfants ont étudié l'effet du choix entre des aliments appréciés de manière équivalente. En effet, donner à un individu le choix entre différents aliments donne également l'opportunité de pouvoir sélectionner l'aliment davantage apprécié. Ainsi, l'effet sur l'appréciation de l'aliment ou la prise alimentaire serait davantage lié à un effet de préférence qu'à un effet du choix *per se*.

1.2.2. Effets modulateurs du choix

Si certains travaux ont montré que le choix pouvait influencer les comportements ultérieurs (tels que le plaisir de manger ou la prise alimentaire), d'autres n'ont montré aucun effet. Une méta-analyse (menée pas uniquement sur les comportements alimentaires) a mis en évidence une série de facteurs pouvant moduler ces effets du choix (Patall et al., 2008). Ainsi des facteurs relatifs à l'individu tels que l'âge, la culture ou les traits psychologiques (par exemple lié à la manière dont un individu fait un choix ou encore le désir de contrôle sur son environnement) peuvent moduler l'effet du choix sur les comportements ultérieurs (Bereby-Meyer et al., 2004; Burger, 1990; Iyengar & Lepper, 1999; Iyengar et al., 2006; Patall et al., 2008; Schwartz et al., 2002). Des facteurs contextuels tels que l'assortiment de produits proposé en situation de choix peuvent également moduler cet effet. Par exemple, le nombre d'options parmi lesquelles un choix est réalisé peut moduler l'effet du choix sur la satisfaction de l'élément choisi et la motivation à acheter. Il a notamment été montré un effet positif du choix lorsque le nombre d'options augmente mais un effet négatif du choix lorsque le nombre d'options devient trop important (Reutskaja & Hogarth, 2009; Shah & Wolford, 2007). Il a été montré plus généralement que l'effet du choix serait modulé par la quantité d'informations disponibles lors du choix pouvant impacter la difficulté à prendre une décision et donc la qualité de la décision finale (Lurie, 2004). La quantité d'informations disponible est fonction du nombre d'options, du nombre d'attributs permettant de différencier les options ou encore du nombre de niveaux par attribut.

1.2.3. Choix et variété

En situation réelle de choix comme en cafétéria ou lors d'un buffet, les individus n'ont pas uniquement la possibilité de choisir un unique aliment, mais peuvent également en choisir plusieurs. Ainsi, pouvoir choisir plusieurs aliments donne également l'opportunité à un individu de consommer une variété d'aliments. Dans cette thèse, le choix a été défini comme l'opportunité pour un individu de sélectionner l'aliment qu'il souhaite consommer. Cette définition fait donc référence à une action résultant d'un processus de prise de décision alors que la variété fait référence à la présentation de plusieurs aliments ayant des caractéristiques sensorielles différentes qu'un individu peut consommer. Le choix et la variété se distinguent donc par définition et leurs effets ont été traités séparément dans la littérature. Cependant, nous avons réalisé une revue non exhaustive des travaux de recherche existants analysant les différents paradigmes mis en place dans les études sur le choix et la variété et avons

montré que ces deux notions étaient fréquemment associées de façon intrinsèque. Dans la littérature, l'effet de la variété a été évalué qu'elle soit séquentielle (i.e. les différents aliments sont présentés successivement) (B. J. Rolls, Rowe, et al., 1981; B. J. Rolls et al., 1984; Spiegel & Stellar, 1990) ou simultanée (i.e. les aliments sont tous servis au même moment) (Bucher et al., 2014; Meengs et al., 2012; Pliner et al., 1980). En situation de variété simultanée, un individu peut sélectionner à chaque bouchée l'aliment qu'il souhaite, incluant donc une part de choix pouvant être qualifiée d'implicite car l'individu n'évoque pas à chaque fois sa décision.

Si les effets du choix sur le plaisir de manger et la prise alimentaire n'ont été que peu explorés jusqu'à aujourd'hui, l'effet de la variété et les mécanismes sous-jacents ont été déjà beaucoup étudiés. Ainsi, il a été montré que consommer une variété d'aliments était associé à une augmentation de la prise alimentaire par rapport à une situation de non-variété (où un seul aliment est consommé) (McCrory et al., 2012; Meengs et al., 2012; Pliner et al., 1980; Raynor & Epstein, 2001; B. J. Rolls, Rowe, et al., 1981; Spiegel & Stellar, 1990). Cet effet serait lié d'une part à un mécanisme pré-ingestif opérant notamment au moment où l'individu se sert car la présentation d'une variété d'aliment (vs. un même aliment) affecterait les quantités perçues (Keenan et al., 2015; Redden & Hoch, 2009; Wilkinson et al., 2013) et d'autre part à un mécanisme sensoriel : consommer différents aliments permet de limiter le déclin d'appréciation lié à la consommation un aliment spécifique (rassasiement sensoriel spécifique) (M. Hetherington et al., 1989; Raynor & Epstein, 2001; Remick et al., 2009; B. J. Rolls, Rolls, et al., 1981).

2. Travaux personnels

2.1. Objectifs de la thèse

Selon la théorie de l'auto-détermination, avoir la possibilité de choisir permet de satisfaire des besoins de compétence et d'autonomie résultant en une augmentation de la motivation intrinsèque à réaliser l'action qui a été choisie et sa satisfaction associée. Cette théorie nous amène donc à l'hypothèse que pouvoir choisir son aliment augmenterait le plaisir de consommer cet aliment et la motivation à le consommer (i.e. consommer en plus grandes quantités). L'étude de l'effet du choix sur le plaisir de manger et la prise alimentaire a fait l'objet de récents travaux de recherche. Peu d'entre eux ont étudié l'effet du choix *per se* (i.e. entre des aliments appréciés de manière similaire). Ils ont principalement été menés chez des enfants et ont montré des résultats divergents. L'objectif principal de cette thèse a donc été d'étudier l'effet du choix entre des aliments appréciés de façon similaire sur l'appréciation de l'aliment choisi et la prise alimentaire chez des adultes.

D'une part, la revue de la littérature a montré précédemment que l'effet du choix pouvait être modulé par des facteurs de contexte liés notamment à l'assortiment de produits parmi lequel un choix est

réalisé. La première partie de cette thèse a eu donc pour objectif d'étudier deux caractéristiques de l'assortiment d'aliments pouvant moduler l'effet du choix sur l'appréciation de l'aliment et la prise alimentaire.

D'autre part, force est de constater que le choix (comme opportunité de sélectionner le ou les aliment(s) que l'on souhaite consommer) est souvent associé à des situations de variété (présentation de plusieurs aliments différents que l'on peut consommer). L'effet du choix et l'effet de la variété sur la prise alimentaire ont été jusqu'à maintenant évalués séparément dans littérature même s'il a été montré que ces deux effets peuvent être intrinsèquement associés. Ainsi, la seconde partie de cette thèse vise à étudier les effets de choix et/ou de variété sur le plaisir de manger et la prise alimentaire.

2.2. Choix et structure de l'assortiment d'aliments

Les résultats de cette étude ont été publiés dans un numéro de la revue Appetite : Parizel O, Sulmont-Rossé C, Fromentin G, Delarue J, Labouré H, Benamouzig R, Marsset-Baglieri A. The structure of a food product assortment modulates the effect of providing choice on food intake. Appetite, in press

La théorie de l'auto-détermination amène à l'hypothèse que pouvoir choisir un aliment augmenterait le plaisir de consommer cet aliment et la prise alimentaire associée. De précédents travaux ont étudié l'effet du choix sur l'appréciation de l'aliment et/ou la prise alimentaire et ont mené à des résultats peu consensuels (Altintzoglou et al., 2015; King et al., 2008, 2004; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Ces études ayant été menées auprès d'individus d'âge différents (enfants, adultes), dans différents contextes (laboratoire et situations réelles) et en considérant différents aliments, il a été suggéré que l'effet du choix pourrait être modulé par des effets de contexte. Il a notamment été montré que l'effet du choix pouvait être modulé par les caractéristiques de l'assortiment de produits (alimentaire et non-alimentaire), tels que le nombre d'alternatives ou le nombre d'attributs différenciant les alternatives (Iyengar & Lepper, 2000; Kahn & Wansink, 2004; Rortveit & Olsen, 2007; Scheibehenne et al., 2010).

Dans des situations réelles de consommation (cafétéria, buffet), les consommateurs peuvent choisir parmi des produits similaires (par exemple, choisir parmi des yaourts de différentes saveurs) ou parmi des aliments assez peu similaires (choisir une entrée parmi des carottes râpées, des betteraves, une salade de tomates...). D'autre part, de précédentes études évaluant l'effet du choix *per se*, ont porté sur des aliments initialement peu appréciés (Altintzoglou et al., 2015; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). On peut ainsi se demander si le choix a le même impact qu'il porte sur des aliments appréciés ou des aliments peu appréciés. Cette étude a donc eu pour objectif d'évaluer l'effet modulateur de la structure de l'assortiment d'aliments sur l'impact du choix en évaluant deux caractéristiques de cet assortiment : (i) le degré de similarité entre les aliments (i.e. choisir parmi des

aliments similaires vs choisir parmi des aliments peu similaires) et (ii) le niveau d'appréciation des aliments (i.e. choisir parmi des aliments appréciés vs choisir parmi des aliments peu appréciés).

2.2.1. Matériel et Méthodes

Deux études de protocole identique mais utilisant des assortiments d'aliments différents ont été réalisées : la première étude « Purées de pommes » a porté sur des purées de pommes variant uniquement selon la texture ; la seconde étude « Desserts » a porté sur un univers de desserts variant selon plusieurs dimensions sensorielles (texture, couleur, saveur...).

Chaque assortiment constitué de douze produits semi-solide a été élaboré pour répondre aux critères suivants : (i) au sein de chaque assortiment, les produits ne devaient pas différer de plus de 20 kcal /100g ; (ii) au sein de chaque assortiment, les produits devaient générer des différences d'appréciation ; (iii) au sein de chaque assortiment, la différence entre les produits devait être perçue visuellement afin de s'assurer que les participants perçoivent un véritable choix entre les différents produits. Les purées de pommes ont été élaborées par modification de la structure d'une même purée de pommes initiale du commerce selon trois paramètres structuraux : la taille des particules (par broyage), la concentration en pulpe (par ajout de pulpe issue d'une étape de centrifugation) et l'ajout de morceaux de pommes. Douze purées de pommes (de valeur énergétique entre 54 kcal/100g et 59 kcal/100g) variant selon la texture et générant des différences d'appréciation ont ainsi été élaborées. Un profil flash mené sur ces purées de pommes a mis en évidence qu'elles variaient principalement selon la texture (plus de 80% des descripteurs sensoriels générés étaient relatifs à la texture) et que ces différences étaient perceptibles visuellement (30% des descripteurs sensoriels étaient visuels). Un test hédonique a montré que ces purées généraient des différences d'appréciation. Douze desserts semi-solides du commerce incluant des produits laitiers, des purées de fruits et des crèmes desserts variant en couleur, texture et saveur (de valeur énergétique entre 99 kcal/100g et 117 kcal/100g) et générant des différences hédoniques ont ainsi été sélectionnés au moyen d'un test hédonique et d'un test de tri libre.

Deux panels de 80 volontaires adultes normo-pondéraux (IMC entre 18,5 et 26 kg/m²) ont été recrutés pour chaque étude (étude « Purée de pommes » : 53 femmes et 27 hommes, âge moyen 24,6±4,7 ans, IMC moyen 21,5±2,1 kg/m² ; étude « Desserts » : 57 femmes et 23 hommes, âge moyen 32,4 ± 5,7 ans, IMC moyen 22,2 ± 2,0 kg/m²). Afin de ne pas influencer leur comportement lors de l'étude, les volontaires n'ont pas eu connaissance du but réel de l'étude et il leur a été expliqué que l'étude portait sur l'appréciation de différentes purées de pommes ou de desserts.

L'étude « Purées de pommes » et l'étude « Desserts » ont suivi le même protocole. Chaque participant a assisté à 3 séances hebdomadaires à l'heure du déjeuner. Le matin de chaque séance, les participants devaient consommer le même petit déjeuner au moins 3h avant le début de l'étude et ne devaient ni

manger ni boire (sauf de l'eau) jusqu'au début de la séance. A chaque séance, les participants ont reçu un plat principal composé de pâtes à la sauce tomate. Lors de la première séance, les participants pouvaient consommer ce qu'ils souhaitaient : la quantité consommée a été mesurée puis resservie aux 2 séances suivantes où les participants devaient consommer les quantités servies. Lors de la première séance et après avoir consommé les pâtes, les 12 produits de l'étude (purées de pommes ou desserts) ont été présentés à chaque participant de façon monadique séquentielle et dont l'ordre a été déterminé selon un carré latin de Williams. Les participants ont donné une note d'appréciation à chaque produit sur une échelle de 0 à 10 (0 : « je n'aime pas du tout » ; 10 : « j'aime beaucoup »). A l'issue de cette première séance, deux groupes de 40 participants ont été constitués : un groupe « Non-plaisant » et un groupe « Plaisant ». Trois produits d'appréciation similaire et peu appréciés (i.e. ayant reçu une note entre 1 et 4 et dont la différence de notation est inférieure à 2 points) ont été sélectionnés pour chaque individu du groupe « Non-plaisant » et trois produits d'appréciation similaire et appréciés (i.e. ayant reçu une note entre 6 et 9 et dont la différence de notation est inférieure à 2 points) ont été sélectionnés pour chaque individu du groupe « Plaisant ». Chaque volontaire a ensuite participé à une séance de choix et une séance de non-choix dont l'ordre a été équilibré. En séance de choix, chaque participant s'est vu présenté les 3 produits parmi lesquels il a en choisi un (sans goûter) qu'il a consommé de façon *ad libitum*. En séance de non-choix, chaque participant s'est vu présenté un produit (sélectionné aléatoirement par l'expérimentateur parmi les 3 attribués à chaque sujet) qu'il a consommé de façon *ad libitum*. A chaque séance, les sujets ont attribué une note d'appréciation du produit consommé à la première bouchée (entre 0 et 10) et les quantités consommées ont été mesurées.

Les quantités consommées de purées de pommes ou de desserts ont été converties en énergie consommée. Pour chaque étude, l'appréciation de chaque produit et la prise alimentaire de purées de pommes et de desserts (en masse et en énergie) évaluées en situations de choix et de non-choix ont été analysées selon un modèle linéaire mixte avec le *groupe* (« Plaisant » et « Non-plaisant ») et la *condition* (choix et non-choix) comme effet fixes, leurs interactions et le participant en effet aléatoire. Les résultats ci-dessous présentent les moyennes associées à leur erreur standard ($M \pm SE$).

2.2.2. Résultats

Dans l'étude « Purées de pommes », les participants du groupe « Plaisant » ont attribué des notes d'appréciation aux purées de pommes consommées plus élevées ($M=7,5 \pm 0,1$) que les participants du groupe « Non-plaisant » ($6,2 \pm 0,2$) ($F(1,78)=24,4$; $p<0,001$). Les participants ont également donné des notes d'appréciation supérieures en situation de choix ($M=7,2 \pm 0,2$) que de non-choix ($M=6,5 \pm 0,2$) ($F(1,78)=20,8$; $p<0,001$). Aucun effet de l'interaction du groupe et de la condition n'a été observé. Cependant, aucun effet (ni du *groupe* ni de la *condition*) n'a été observé sur la prise alimentaire des purées (ni en quantité ni en énergie consommée).

Dans l'étude « Desserts », les participants du groupe « Plaisant » ont attribué des notes d'appréciation aux desserts consommés plus élevées ($M=7,8\pm0,2$) que les participants du groupe « Non-plaisant » ($M=5,5\pm0,3$) ($F(1,78)=48,4$; $p<0,001$). Les participants ont également attribué des notes d'appréciation supérieures en situation de choix ($M=6,9\pm0,2$) que de non-choix ($M=6,3\pm0,3$) ($F(1,78)=5,5$; $p<0,05$). Aucun effet de l'interaction du groupe et de la condition n'a été observé sur les notes d'appréciation. Les participants du groupe « Plaisant » ont également consommé davantage de desserts (en masse : $M=217\pm12$ g ; en énergie : $M=231\pm12$ kcal) que les participants du groupe « Non-Plaisant » (en masse : $M=139\pm10$ g ; en énergie : $M=145\pm10$ kcal) (en masse : $F(1,78)=16,3$; $p<0,001$; en énergie : $F(1,78)=18,1$; $p<0,001$). Les volontaires ont également consommé plus de desserts en situation de choix (en masse : $M=192\pm12$ g ; en énergie : $M=202\pm13$ kcal) qu'en situation de non-choix (en masse : $M=164\pm11$ g ; en énergie : $M=173\pm11$ kcal) (en masse : $F(1,78)=9,2$; $p<0,01$; en énergie : $F(1,78)=8,5$; $p<0,01$). Aucun effet de l'interaction du *groupe* et de la *condition* n'a été observé sur la prise alimentaire. Dans cette étude, donner à un individu la possibilité de choisir son dessert augmente l'énergie consommée de 17% par rapport à une situation où un dessert a été imposé.

2.2.3. Discussion

Les résultats de cette étude ont montré que donner la possibilité de choisir entre des alternatives appréciées de façon similaire augmentait l'appréciation des purées de pommes et des desserts consommés. Les individus ont consommé davantage en situation de choix que de non-choix seulement lorsque le choix a porté sur des produits d'une même catégorie (étude « Desserts ») alors qu'aucune influence du choix n'a été observée lorsque celui-ci a porté sur différentes variantes d'un même produit (étude « Purées de pommes »). De précédentes études évaluant l'effet du choix sur la prise alimentaire ont également mené à des résultats divergents (Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010) supportant le fait que l'influence du choix sur la prise alimentaire serait vulnérable aux effets de contexte.

Cette étude a montré que le degré de similarité entre les alternatives peut moduler l'effet du choix sur les comportements de consommation. Dans l'étude « Purées de pommes », les produits variaient selon une modalité sensorielle (la texture) alors que dans l'étude « Desserts », les produits variaient selon plusieurs modalités sensorielles (l'aspect, la flaveur, la texture). Nous pouvons faire l'hypothèse que dans la seconde étude, les participants auraient perçu un degré plus important de variété lorsqu'ils ont réalisé leur choix. Kahn and Wansink (2004) ont précédemment mis en évidence que la structure de l'assortiment pouvait influencer la variété perçue de cet assortiment et que la variété perçue pouvait moduler les quantités consommées. Nous pouvons également mettre nos résultats au regard de ceux de B. J. Rolls, Rowe, et al. (1981) qui ont montré que l'effet de variété (comme étant la présentation de plusieurs aliments différents pouvant être consommés) ne serait observé que lorsque les produits seraient suffisamment dissimilaires. Il est néanmoins important de noter que lorsqu'un assortiment

devient trop complexe (lié au nombre d'attributs différenciant les options mais également au nombre d'options associé au degré de similarité entre les attributs, le degré de difficulté à catégoriser les alternatives...), les individus pourraient avoir des difficultés à traiter l'ensemble des informations disponibles pouvant mener à de la frustration et décourager à consommer (Scheibehenne et al., 2010). Des études complémentaires seraient donc nécessaires afin de préciser le degré de similarité à partir duquel les produits sont suffisamment dissimilaires pour observer un effet positif du choix sur la prise alimentaire, notre étude ayant montré qu'une variation selon une seule dimension sensorielle (ici la texture) ne serait pas suffisante.

De plus, ces deux études ont montré le niveau d'appréciation des aliments (i.e. choisir parmi des aliments appréciés vs choisir parmi des aliments peu appréciés) pas l'effet du choix (ni sur le plaisir de manger ni sur la prise alimentaire). S'il est important de noter une évolution des notes d'appréciation des produits sélectionnés pour le groupe « Non-plaisant » entre la séance 1 et les séances de choix et non-choix (de 2,7 à 6,2 et de 2,5 à 5,5 pour les purées de pommes et les desserts respectivement), les produits sélectionnés dans le groupe « Non-plaisant » restent significativement moins appréciés que ceux sélectionnés dans le groupe « Plaisant » au cours de séances de choix et de non-choix. Nous pouvons émettre l'hypothèse qu'au cours de la première séance un effet de contraste hédonique a pu apparaître, selon lequel la présence d'alternatives plaisantes rendent celles moins plaisantes encore moins appréciées (Hayes, DePasquale, & Moser, 2011; Zellner et al., 2006).

En conclusion, cette étude avait pour objectif d'évaluer deux caractéristiques de l'assortiment d'aliments pouvant moduler l'effet du choix sur le plaisir de manger et la prise alimentaire : (i) le degré de similarité entre les aliments (i.e. choisir parmi des aliments similaires vs choisir parmi des aliments peu similaires) et (ii) le niveau d'appréciation des aliments (i.e. choisir parmi des aliments appréciés vs choisir parmi des aliments peu appréciés). Les résultats ont montré que lorsque les individus peuvent choisir un dessert pendant leur repas, l'appréciation du produit choisi était augmentée par rapport à une situation où cet aliment est imposé. Ce résultat est associé à une augmentation de la quantité consommée si le choix porte sur des desserts suffisamment différents. L'effet du choix sur le plaisir de manger et la prise alimentaire est identique qu'il porte sur des produits appréciés ou non appréciés. Des travaux complémentaires seraient nécessaires pour préciser les conditions sous lesquelles le choix influence la prise alimentaire, notamment en ce qui concerne la structure de l'assortiment d'aliments (nombre d'options, degré de différence sensorielle).

2.3. Choix et variété

Les résultats de cette étude ont été soumis: Parizel O, Labouré H, Marsset-Baglieri A, Fromentin G, Sulmont-Rossé C. Providing choice and/or variety during a meal: impact on vegetable liking and intake.

Actuellement, la restauration hors foyer de type cafétéria ou buffet offre non seulement à un consommateur la possibilité de choisir un élément de repas parmi plusieurs alternatives (choix d'une entrée, d'un dessert parmi plusieurs propositions) mais également la possibilité d'associer plusieurs alternatives (choisir plusieurs accompagnements du plat principal). Dans de telles situations, les consommateurs font donc face à des situations de choix (défini comme l'opportunité pour un individu de sélectionner l'aliment qu'il souhaite consommer et de variété (définie comme la présentation de plusieurs aliments ayant des caractéristiques sensorielles différentes qu'un individu peut consommer).

D'une part, il a été montré que le choix pouvaient influencer le plaisir de manger et/ou les quantités consommées chez les adultes (King et al., 2008, 2004; Parizel et al., 2015) et d'autre part, servir différents aliments à un individu pouvait augmenter la prise alimentaire (McCrory et al., 2012; Meengs et al., 2012; Pliner et al., 1980; Raynor & Epstein, 2001; B. J. Rolls, Rowe, et al., 1981; Spiegel & Stellar, 1990)

Néanmoins, ces effets ont été jusqu'à maintenant étudié séparément alors qu'ils peuvent apparaître simultanément dans des situations réelles de consommation. Cette étude a donc eu pour objectif d'étudier l'impact de situations de choix et/ou de variété sur le plaisir de manger et la prise alimentaire chez les adultes en comparant 4 situations auxquelles un individu peut être confronté : (i) se voir servir un aliment (non-choix/non-variété), (ii) choisir un aliment parmi plusieurs alternatives (choix/non-variété), (iii) se voir présenter plusieurs aliments (non-choix/variété) et (iv) choisir autant d'aliments souhaités parmi plusieurs alternatives (choix/variété).

2.3.1. Matériel et Méthodes

Les légumes représentent un élément de repas pouvant être présenté sous les 4 conditions expérimentales de façon écologique. Ils ont donc été choisis comme l'élément de repas sur lequel portera le choix et/ou la variété. Un questionnaire diffusé en ligne auprès de 205 individus et portant sur 27 recettes de légumes verts a permis de sélectionner trois recettes les plus communément consommées et appréciées de façon similaire : des courgettes à l'huile d'olive ($M=7,7\pm 0,2$), des haricots au beurre ($M=7,4\pm 0,1$) et des épinards à la crème ($M=7,4\pm 0,2$). Des recettes de courgettes à l'huile d'olive (43 kcal/100g), de haricots verts au beurre (56 kcal/100g) et d'épinards à la crème (63 kcal/100g) ont été élaborées de telle sorte qu'elles ne diffèrent pas de plus de 20 kcal/100g tout en correspondant aux recettes communément consommées en France. Les recettes ont été cuisinées le matin de chaque séance puis réchauffées au micro-onde pendant les séances.

Cinquante-neuf adultes (hommes et femmes entre 18 et 40 ans) normo-pondéraux ont été recrutés via un questionnaire en ligne. Les volontaires recrutés devaient également avoir déjà consommé les trois recettes de légumes, les apprécier de manière équivalente, (c'est-à-dire avoir donné des notes d'appréciation différant de moins de 2 points sur une échelle de 0 à 10, 0 : « je n'aime pas du tout »,

10 : « j'aime beaucoup ») et ne pas les rejeter (i.e. avoir donné des notes d'appréciation supérieures à 2 points sur cette même échelle). Afin de ne pas influencer leur comportement, les volontaires n'ont pas eu connaissance du but réel de l'étude et il leur a été expliqué que l'étude portait sur l'influence des boissons de fin de repas sur les sensations de faim.

Les volontaires ont participé à 4 séances aux heures de déjeuner et séparées d'au moins 4 jours. Le matin de chaque séance, les participants devaient consommer le même petit déjeuner au moins 3h avant le début de l'étude et ne devaient ni manger ni boire (sauf de l'eau) jusqu'au début de la séance. Un repas composé de légumes a été proposé selon les 4 conditions expérimentales suivantes dont l'ordre a été équilibré selon un carré latin de Williams. En situation de non-choix/non-variété (NC/NV), une recette de légumes (tirée au hasard parmi les 3 recettes) a été servie au participant en portion de 400g. En situation de choix/non-variété (C/NV), les 3 recettes de légumes ont été présentées sous forme d'échantillon au participant simultanément parmi lesquelles il n'en choisit qu'une dont il a été servi une portion de 400g. En situation de non-choix/variété (NC/V), les 3 recettes de légumes ont été servies simultanément en portion de 133g chacune au participant. En situation de choix/variété (C/V), les 3 recettes de légumes ont été présentées simultanément sous forme d'échantillon au participant parmi lesquelles il a pu choisir ce qu'il souhaitait (1, 2 ou 3 recettes) et dont il lui a été servi une portion totale de 400g (soit 400g si le participant a choisi 1 recette, 200g de chaque recette s'il en a choisi 2 ou 133g de chaque recette s'il en a choisi 3). Les participants pouvaient manger les quantités de légumes souhaitées et pouvaient demander à être resservis. Les légumes ont été accompagnés de jambon dont la quantité consommée, fixée lors de la première séance, a été identique lors des 4 séances. Une compote de pommes et un thé ont ensuite été servis (afin de conserver la cohérence avec le prétexte de l'étude énoncé). A la fin de chaque séance, chaque volontaire a donné une note d'appréciation de chaque élément de repas consommé (légumes, jambon, compote de pommes) entre 0 et 10 (0 : « je n'aime pas du tout ; 10 : « j'aime beaucoup »). A l'issue de la dernière séance, chaque participant a donné une note d'appréciation pour chacune des trois recettes de légumes entre 0 et 10 (même échelle que précédemment). Chaque participant a ensuite été pesé et mesuré.

Les notes d'appréciation attribuées au plat de légumes et les quantités consommées à chaque séance ont été soumises à un modèle linéaire mixte à 2 facteurs avec la *condition* (NC/NV; NC/V; C/NV; C/V) et la *position de la séance* en effets fixes et le *participant* en effet aléatoire puis à un modèle linéaire mixte à 3 facteurs avec le *choix* (choix, non-choix), la *variété* (variété, non-variété), leur interaction et la *position de la séance* (1, 2, 3, 4) en effets fixes et le *participant* en effet aléatoire (la *position de la séance* correspond au rang d'apparition de chaque séance et a été pris en compte afin d'évaluer un potentiel effet de lassitude au cours des 4 séances). Les résultats ci-dessous présentent les moyennes associées à leur erreur standard (M±SE).

2.3.2. Résultats

Cinquante-neuf volontaires ont été initialement recrutés mais 2 volontaires n'ont pas assisté à l'ensemble de l'étude et 3 volontaires ont sous-estimé leur poids lors du recrutement dans le questionnaire en ligne (IMC supérieur à 26 kg/m²) ont donc été exclus des résultats de l'étude. D'autre part, 10 participants n'ont choisi qu'une recette de légumes en situation de choix/variété : n'étant pas en situation de variété, leurs données n'ont pas été incluses dans l'analyse des résultats. Les résultats de 44 participants ont donc été analysés (38 femmes et 6 hommes ; âge moyen 27±6,5 ans (écart type), IMC moyen 21,7±2,2 kg/m², scores moyen de TFEQ-D et de TFEQ-R de 6,1±2,6 et 6,2±3,5 respectivement).

Parmi les 44 participants, 9 individus ont consommé l'intégralité des portions de légumes servis lors des 4 séances (qu'ils aient été resservis ou non). Ces individus ont été considérés comme des *plate clearers*, c'est à dire comme des individus ayant une tendance à terminer leur assiette, qu'ils se soient servis eux même ou non leur portion (Fay et al., 2011; Hinton et al., 2013; Robinson et al., 2015; Wansink & Johnson, 2015). Il a été suggéré que ces individus seraient donc peu sensibles aux signaux internes tels que les sensations de faim ou aux signaux externes tels que les facteurs de contexte. Ainsi, les résultats de cette étude ont été analysés sur l'ensemble de la population (n=44) puis sur la population sans *plate clearers* (n=35).

Sur l'ensemble de la population (n=44), les résultats du modèle linéaire mixte à 2 facteurs mettent en évidence que les participants ont attribué des notes d'appréciation supérieures en situations de choix/variété (M=7,7±0,2), de non-choix/variété (M=7,3±0,2) et de choix/non-variété (M=7,4±0,2) qu'en situation de non-choix/non-variété (M=6,6±0,3) (F(3,124)=7,6 ; p<0,001) mais aucun effet de la condition n'a été observé sur la prise alimentaire. Le modèle linéaire mixte à 3 facteurs met en évidence que les participants ont attribué des notes d'appréciation supérieures en situation de choix (M=7,5±0,2) que de non-choix (M=6,9±0,2) (F(1,124)=11,6 ; p<0,001) et ont donné des notes d'appréciation supérieures en situation de variété (M=7,5±0,2) que de non-variété (M=7,0±0,2) (F(1,124)=9,2 ; p<0,01). Aucun effet de l'interaction du choix et de la variété n'a été observé sur les notes d'appréciation. D'autre part, aucun effet du choix et de la variété n'a été mis en évidence sur la prise alimentaire des légumes.

Sur la population n'incluant pas les *plate clearers* (n=35), les résultats du modèle linéaire mixte à 2 facteurs sur les notes d'appréciation et la prise alimentaire ont mis en évidence que les participants ont attribué des notes d'appréciation supérieures en situations de choix/variété (M=7,6±0,3), de non-choix/variété (M=7,2±0,3) et de choix/non-variété (M=7,3±0,3), qu'en situation de non-choix/non-variété (M=6,4±0,3) (F(3,97)=5,7 ; p<0,01) et ont consommé davantage de légumes en situations de choix/non-variété (M=336±17g) et de choix/variété (M=336±13g) qu'en situation de non-choix/non-variété (M=300±15g) (F(3,97)=2,8 ; p<0,05). Les résultats du modèle linéaire mixte à 3 facteurs ont

révélé que les participants ont attribué des notes d'appréciation supérieures en situation de choix ($M=7,4\pm0,2$) qu'en situation de non-choix ($M=6,8\pm0,2$) ($F(1,97)=9,3$; $p<0,01$) et des notes d'appréciation supérieures en situation de variété ($M=7,4\pm0,2$) qu'en situation de non-variété ($M=6,9\pm0,2$) ($F(1,97)=6,3$; $p<0,05$). Les participants ont consommé davantage de légumes en situation de choix ($M=336\pm10g$) que de non-choix ($M=310\pm12g$) ($F(1,97)=6,5$; $p<0,05$) mais aucun effet de la variété n'a été observé sur la prise alimentaire des légumes. D'autre part, aucun effet de l'interaction du choix et de la variété n'a été mis en évidence sur les notes d'appréciation et la prise alimentaire des légumes.

Aucun effet de la recette n'a été observé sur les notes d'appréciation données à la fin de l'étude, ni pour l'ensemble de la population ($n=44$) (haricots verts: $M=6,7\pm0,2$; courgettes : $M=7,4\pm0,3$; épinards : $M=7,0\pm0,3$), ni sur la population sans *plate clearers* (haricots verts : $M=6,5\pm0,3$; courgettes : $M=7,2\pm0,4$; épinards : $M=7,0\pm0,3$). Nous observons une différence moyenne de notation de $2,5\pm0,3$ points sur l'ensemble de la population et de $2,7\pm0,3$ pour la population n'incluant pas les *plate clearers*.

2.3.3. Discussion

Les résultats de cette étude ont montré que le choix et la variété augmentaient l'appréciation des aliments consommés sur l'ensemble des individus comme sur les individus n'ayant pas de tendance à être *plate clearer*. Cependant, seul un effet du choix a été observé sur les participants n'étant pas *plate clearers* : on observe une augmentation de 8% sur les quantités consommées de légumes en situations de choix par rapport aux situations de non-choix. Aucun effet de la variété n'a été observé sur la prise alimentaire des légumes. D'autre part, nous n'avons pas observé d'effet de synergie entre le choix et la variété ni sur l'appréciation des aliments consommés ni sur la prise alimentaire (l'appréciation des aliments et la prise alimentaire n'étaient pas supérieures en situation de choix/variété qu'en situations de non-choix/variété et de choix/non-variété).

Dans des situations réelles de consommation comme dans les designs expérimentaux, le choix et la variété sont souvent confondus. D'une part, une situation de choix peut être associée à de la variété lorsque les individus peuvent sélectionner plusieurs alternatives à consommer. D'autre part, une situation de variété simultanée inclut du choix car les individus peuvent choisir à chaque bouchée quel aliment consommer. Nous ne pouvons donc pas écarter le fait qu'un effet de choix intervient et est inhérente à une situation de variété simultanée comme l'ont mentionné de précédents auteurs (Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Nous pouvons néanmoins noter que les situations de choix de notre étude (choix/variété et choix/non-variété) font référence à des choix explicites où le participant formule sa décision à l'expérimentateur alors que les situations de variété

(choix/variété et non-choix/variété) incluent un choix implicite où le participant peut choisir mais sans le formaliser clairement.

Notre étude a également mis en évidence que 9 participants ont fini leur assiette à chacune des 4 séances et avons émis l'hypothèse que ces individus, considérés comme des *plate clearers*, seraient moins sensibles aux signaux internes (sensations de faim) ou externes (facteurs de contexte) : les quantités consommées dépendraient principalement des quantités d'aliments présentes dans leur assiette. L'analyse des résultats sur les individus ne montrant pas cette tendance a révélé un effet du choix sur la prise alimentaire. Ainsi, cette étude met également en évidence que les individus sont différemment sensibles aux signaux conditionnant la fin du repas : dans le même état de faim, certains individus sont influencés par les portions servies dans leur assiette alors que d'autres individus seraient davantage sensibles à des signaux extérieurs tels que la possibilité d'avoir choisi son aliment.

Cette étude a montré que le choix a un effet positif sur l'appréciation des aliments choisis puis consommés ainsi que sur les quantités ingérées, comme cela a déjà été mis en évidence par d'autres auteurs (Altintzoglou et al., 2015; Parizel et al., 2015; Rohlf's Domínguez et al., 2013). Ces résultats pourraient soutenir l'hypothèse de la théorie de l'auto-détermination selon laquelle le choix permet de satisfaire les besoins psychologiques de compétence et d'autonomie menant à une augmentation de la satisfaction et de la motivation à consommer (Patall et al., 2008; Ryan & Deci, 2000). Cependant, avoir la possibilité de choisir l'aliment à consommer donne également l'opportunité de choisir un aliment que l'on apprécie davantage, pouvant donc influencer le plaisir de manger et les quantités consommées. Dans notre étude, nous avons souhaité limiter cet effet de « préférence » en recrutant des participants ayant déclaré apprécier de façon équivalente les trois recettes de légumes et les notes d'appréciation attribuées à la fin de l'étude n'ont pas montré de différence significative entre les trois recettes. Néanmoins, nous ne pouvons pas exclure que certains participants ont consommé davantage de légumes en situations de choix et de variété car ces situations leur ont donné l'opportunité de choisir la recette qu'ils appréciaient individuellement par rapport à la situation de non-choix/non-variété.

Contrairement à ce qu'il était attendu d'après la littérature (Meengs et al., 2012; B. J. Rolls, Rolls, et al., 1981; B. J. Rolls et al., 1984; Spiegel & Stellar, 1990), notre étude n'a pas révélé d'effet de la variété sur la prise alimentaire. Cependant, il a déjà été mis en évidence une absence d'effet de variété lorsque les aliments n'étaient pas suffisamment différents d'un point de vue sensoriel (B. J. Rolls, Rowe, et al., 1981). Si Meengs et al. (2012) avaient montré un effet de la variété lorsque 3 légumes variant en texture, goût, forme et couleur étaient présentés simultanément, notre étude n'a pas montré d'effet lorsque la variété portait sur les légumes verts (i.e. variant en texture, goût, forme mais pas en couleur). En proposant des légumes verts, nous pouvons également suggérer qu'un effet de catégorisation ait contribué à cette absence d'effet : certains participants de l'étude ont pu considérer

les 3 recettes comme des « légumes verts » plutôt que 3 recettes distinctes de légumes (haricots verts, courgettes et épinards). Redden (2006) a ainsi montré que le plaisir de manger diminuait plus rapidement lorsque des individus considéraient des bonbons comme appartenant à une même catégorie que lorsque les individus les considéraient comme étant des bonbons de saveurs différentes. Cet auteur a suggéré qu'en réalisant des sous-catégories d'aliments, les consommateurs attacheraient davantage d'importance aux différences entre les aliments et percevraient leur consommation comme moins répétitive.

En conclusion, cette étude avait pour objectif d'étudier l'impact de situations de choix et/ou de variété sur le plaisir de manger et la prise alimentaire chez les adultes en comparant 4 situations auxquelles un individu peut être confronté en situations de cafétéria ou de buffet. Les résultats ont montré que donner du choix et de la variété augmentait l'appréciation des aliments consommés mais que seul le choix influençait les quantités consommées. Contrairement à ce qui était attendu au regard de la littérature, aucun effet de la variété n'a été observé sur la prise alimentaire des légumes et avons supposé que les trois recettes de légumes verts ne suscitaient pas suffisamment de différences sensorielles. Ainsi, cette étude n'a pas mis en évidence d'effet de synergie entre le choix et la variété, pouvant être dû à l'absence d'effet de variété. Des études complémentaires portant sur des produits davantage différents avant de conclure de l'absence d'effet d'interaction entre le choix et la variété sur la prise alimentaire.

3. Discussion et perspectives

Cette thèse avait pour objectif principal d'étudier l'effet de donner à un individu l'opportunité de choisir ses aliments au cours d'un repas sur le plaisir de manger et la prise alimentaire. Trois études comportementales menées auprès d'adultes normo-pondéraux ont montré que choisir parmi des aliments appréciés de manière similaire augmentait l'appréciation de ces aliments. Cet effet sur l'appréciation a été observé pour différentes catégories d'aliments (légumes d'un plat principal et desserts). Ces études ont également mis en évidence que le choix pouvait augmenter les quantités consommées mais que cet effet serait davantage vulnérable aux effets de contexte, tels que l'assortiment d'aliments.

3.1. Mécanismes de l'effet du choix et choix expérimentaux

La théorie de l'auto-détermination nous avait amené à l'hypothèse que donner à un individu l'opportunité de choisir l'aliment qu'il souhaite consommer augmenterait le plaisir de consommer cet aliment et la motivation à le consommer. Ainsi, les travaux de cette thèse ont évalué l'effet du choix *per se*, c'est-à-dire l'effet de choisir son ou ses aliment(s) parmi des options appréciées de manière équivalente afin de ne pas induire un effet de « préférence ». Les résultats présentés dans cette thèse soutiennent ainsi l'hypothèse issue de la théorie de l'auto-détermination mais ne nous permettent pas

de conclure sur les mécanismes sous-jacents à cet effet. Ces études étaient observationnelles et avaient pour objectif de ne pas influencer le comportement des participants en attirant leur attention par des questions complémentaires. Des études complémentaires permettraient ainsi de préciser le mécanisme ayant opéré en évaluant par exemple via des questionnaires sur le désir de manger (incluant une composante motivationnelle) (Blundell et al., 2010; Mela, 2006) ou encore sur la satisfaction des besoins psychologiques (d'autonomie et de compétence notamment) (Amoura et al., 2013; Gillet et al., 2008). De même, des études d'imagerie cérébrale pourraient apporter des éléments de réponses complémentaires concernant les effets des choix sur la valeur affective de l'aliment choisi et la motivation.

Si les études menées au cours de cette thèse avaient pour objectif d'évaluer l'effet du choix *per se* sur l'appréciation de l'aliment choisi et la prise alimentaire associée, certains facteurs d'influence sont difficilement dissociables d'une situation de choix. D'une part, donner le choix à un individu de sélectionner son aliment lui donne également l'opportunité de consommer l'aliment qu'il préfère. Afin de s'affranchir de cet effet de « préférence », les études mises en place dans cette thèse ont porté sur des choix parmi des produits appréciés de manière équivalente, comme dans les précédents travaux de la littérature (Altintzoglou et al., 2015; Rohlf's Domínguez et al., 2013; Zeinstra, Renes, et al., 2010). Malgré ce contrôle, l'évaluation hédonique peut être modulée par différentes influences tels que l'effet d'exposition (les participants assistaient à plusieurs séances) (Frøst, 2006) ou le contraste hédonique (dans les études sur les purées de pommes et les desserts) (Zellner et al., 2006). D'autre part, le choix et la variété (malgré des différences de définitions et de mécanismes) peuvent s'avérer difficile à dissocier. Il a ainsi été mis en évidence qu'une situation de variété simultanée dans laquelle un individu se voit servir différents aliments est également associée à un choix implicite où l'individu peut choisir à chaque bouchée quel aliment manger.

3.2. Caractéristiques de l'assortiment d'aliments

Les résultats des études de cette thèse et de précédents travaux de recherche (B. J. Rolls, Rowe, et al., 1981) mettent en évidence que les effets du choix et de la variété sur la prise alimentaire pouvaient être modulés par la structure de l'assortiment d'aliments et notamment le degré de similarité entre les produits. Dans la première partie de la thèse, seule l'étude portant sur les desserts (i.e. produits variant selon différentes modalités sensorielles) a montré une augmentation de la prise alimentaire en situation de choix (vs de non-choix). La deuxième partie de la thèse a mis en évidence une absence d'effet de variété sur les quantités consommées lorsque trois légumes verts étaient présentés simultanément.

Si les effets du choix et de la variété montrent une vulnérabilité commune au degré de similarité entre les aliments, il est important de noter dans un premier temps que leurs effets seraient liés à des mécanismes différents. L'effet du choix sur les comportements alimentaires impliquerait un processus

cognitif (dans le sens où l'augmentation de la satisfaction et la motivation seraient la résultante de la satisfaction de besoins psychologiques) alors que l'effet de la variété ferait appel à la fois des processus cognitifs (la variété affectant la représentation des quantités avant la consommation) et sensoriel (consommer une variété d'aliments limite les effets du rassasiement sensoriel spécifique). Mieux comprendre comment un assortiment d'aliments peut moduler les effets du choix et de variété implique donc d'étudier comment les caractéristiques d'un assortiment d'aliments influenceraient les perceptions cognitives et sensorielles d'un individu face à cet assortiment.

D'un point de vue méthodologique, il n'existe actuellement pas de méthode permettant d'évaluer le degré de similarité d'un assortiment généralisable à tout espace-produits. Des méthodes existantes en analyse sensorielle (telles que le profil flash ou le tri-libre utilisées dans l'élaboration des assortiments de purées de pommes et de desserts) peuvent donner des informations sur la proximité perçue des options au sein de chaque assortiment mais ces informations restent relatives à l'espace-produits étudié. Néanmoins, des caractéristiques de l'assortiment tels que le nombre d'options, le nombre et la nature des attributs différenciant les options, la facilité à réaliser des catégories entre les options seraient des caractéristiques communes pouvant moduler les effets du choix et de la variété. Une méthodologie évaluant le degré de similarité d'un assortiment d'aliments pourrait donc inclure l'évaluation de ces caractéristiques.

3.3. Choix de l'aliment : une stratégie efficace ?

Les résultats de cette thèse ont montré que donner à un individu le choix de son dessert ou de légumes pouvaient augmenter la prise alimentaire de ces aliments de 17% et 8% respectivement. Ainsi, comme de précédents travaux l'ont étudié précédemment (Perry et al., 2004), donner le choix pourrait être un levier d'action permettant d'améliorer l'acceptabilité de certains aliments et favoriser leur consommation. Les deux premières études de cette thèse ont également montré que l'effet du choix était similaire qu'il porte sur des aliments appréciés ou peu appréciés initialement. Avant de pouvoir formuler de telles recommandations, certains points ont été abordés ci-dessous.

D'une part, ces études ont été menées dans des conditions expérimentales spécifiques de laboratoire : l'appréciation des aliments était contrôlée et il n'y avait pas d'interactions entre les participants. Dans des conditions réelles de choix, divers facteurs peuvent également influencer les comportements alimentaires. Comme évoqué précédemment, il est courant qu'en situation réelle de choix certains aliments soient davantage appréciés que d'autres. Il a été largement montré que consommer un aliment davantage apprécié augmentait la prise alimentaire (Bolhuis et al., 2012; De Graaf et al., 1999). En situation réelle de choix, un effet cognitif lié à l'opportunité de choisir son aliment et un effet de « préférence » pourraient donc influencer la prise alimentaire. Il n'est cependant pas possible de conclure sur l'interaction de ces effets d'après les résultats de cette étude. D'autre part, dans certaines

situations de choix de type cafétéria, les individus ont la possibilité de choisir leurs aliments mais pas toujours les quantités alors que dans des situations de type buffet, les individus ont la possibilité de choisir leurs aliments mais se servent également eux même les quantités qu'ils souhaitent consommer. Adams et al. (2005) cependant n'ont pas observé de différence de prise alimentaire entre une situation de self-service où les individus peuvent choisir eux même les quantités et une situation où les quantités sont pré-déterminées. Ainsi en situation réelle de choix, d'autres facteurs liés aux interactions sociales, l'accès au prix, où une disposition de certains aliments les rendant plus accessibles peuvent également influencer la prise alimentaire (Cohen & Babey, 2012). Il a par ailleurs été suggéré que l'interaction sociale modulait l'effet du choix dans une étude menée par dans laquelle les enfants faisaient des choix en restaurant en compagnie de leurs parents alors que Rohlf's Dominguez et al. (2013) ont montré un effet positif du choix sur la prise alimentaire dans une étude de paradigme très similaire mais menée auprès d'enfants à la cantine et déjeunant donc avec leurs pairs.

D'autre part, ces études ont montré que le choix pouvait augmenter la prise alimentaire de l'aliment choisi mais nous pouvons nous demander si cet effet persiste sur le long terme. En effet, une augmentation de la prise alimentaire peut être compensée au cours du repas même ou sur la journée (Almiron-Roig et al., 2013). Dans l'étude sur les légumes, nous n'avons notamment pas observé de différences de prise alimentaire de la purée de pommes ni sur la totalité de l'énergie consommée au cours du repas entre les 4 conditions étudiées. De précédents résultats de la littérature ont également montré un effet de la variété sur les quantités consommées de légumes mais aucun effet à l'échelle du repas et il a été suggéré que la variété de légumes favoriserait la constitution d'un repas plus équilibré (Bucher et al., 2014).

Enfin, nos études ont porté sur la présentation de situations de choix ou de variété ponctuelles. Cependant, qu'en est-il lorsqu'un individu est quotidiennement soumis à des situations de choix, comme en restauration collective ? De Wild et al. (2015) ont notamment montré que des enfants soumis à des choix entre 2 légumes au cours de 12 repas consommaient davantage de légumes que des enfants non-exposés à du choix répété. Concernant la variété proposée sur le long terme, les études ont principalement porté sur la proposition d'aliments différents à chaque repas (versus de la monotonie où un même aliment était proposé à plusieurs repas) mais pas d'étude n'a, à notre connaissance, porté sur l'effet de proposer plusieurs aliments à chaque repas.

Enfin, nos études ont porté sur des adultes et la généralisation de ces résultats nécessitent des études portant sur d'autres catégories d'âge dans le sens où l'âge a été identifié comme un facteur modulateur de l'effet du choix. Des études ont déjà montré que l'effet du choix impactait la prise alimentaire des enfants (Altintzoglou et al., 2015; de Wild et al., 2015; Rohlf's Domínguez et al., 2013). Concernant les personnes âgées, les études n'ont pas évalué l'effet du choix *per se* : le choix était un levier d'action parmi d'autres facteurs permettant d'améliorer le contexte du repas.

4. Conclusion

Cette thèse avait pour objectif principal d'étudier l'effet d'offrir à un individu l'opportunité de choisir ses aliments au cours d'un repas sur le plaisir de manger et la prise alimentaire. Les résultats confirment l'hypothèse issue de la théorie de l'auto-détermination et les résultats de précédents travaux : donner à un individu l'opportunité de choisir ses aliments parmi différentes options augmenterait l'appréciation des aliments sélectionnés et, dans certaines conditions, la prise alimentaire. L'effet du choix sur la prise alimentaire serait en effet sensible à des facteurs de contexte tels que la structure de l'assortiment d'aliments présentés. Les trois études comportementales présentées dans cette thèse ont été menées auprès d'adultes normo-pondéraux dans des conditions expérimentales contrôlées. Dans des situations réelles de consommation telles qu'en cafétéria ou lors d'un buffet, d'autres facteurs environnementaux tels que la possibilité de consommer différents aliments (effets variété) ou les interactions sociales peuvent également influencer la prise alimentaire.

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Title : Providing food choices during a meal: Impact on food liking and food intake

Keywords : choice, variety, food intake, food product assortment

Abstract :

Out-of-home catering services frequently offer consumers the opportunity to choose their foods from among different proposals and/or provide consumers with a variety of food. The present thesis aimed at investigating the effect of providing choice of equally-liked foods during a meal on food liking and food intake in healthy, normal-weight adults. The first part focused on two characteristics of a food product assortment (desserts) as modulator factors of the choice effect: (i) the degree of similarities between desserts and (ii) the level of pleasantness of desserts. Two independent behavioral studies using the same paradigm were carried out in adults (n=80 for each experiment) who participated in a choice and a no-choice session. Providing choice enhanced food liking no matter the degree of similarity between the desserts, but enhanced food intake only when products were sufficiently dissimilar. The choice effect on food liking and food intake was not modulated by the level of pleasantness of alternatives. The second part of the thesis assessed the impact of choice and/or variety on food liking and food intake. Fifty-nine adults participated in a 4-session study where they consumed vegetable dishes under the four following conditions: (i) being served one dish (no-choice/no-variety); (ii) being served the three dishes (no-choice/variety); (iii) choosing one dish from among three (choice/no-variety) and (iv) choosing as many dishes as wanted (choice/variety). Providing choice increased vegetable liking and vegetable intake, while offering a variety of vegetables only increased their liking. No synergy effect between choice and variety was observed on vegetable liking and vegetable intake (i.e. the effect in the choice/variety condition was not significantly higher than the effects in the no-choice/variety and choice/no-variety conditions). It may be then concluded that providing choice of food to adults increases food liking even when choice is made among similarly-liked foods. Regarding choice and variety effects, however, their impacts on food intake appear to be vulnerable to contextual factors, and especially, the degree of similarity between food options.

Titre : Proposer du choix pendant un repas : impact sur le plaisir de manger et la prise alimentaire

Mots clés : choix, variété, plaisir, prise alimentaire, assortiment

Résumé :

La restauration collective s'organise autour de modèles de type cafétéria ou buffet offrant aux consommateurs la possibilité de choisir le (ou les) aliments qu'ils souhaitent consommer. L'objectif de cette thèse était d'étudier les effets de donner l'opportunité à un individu de choisir ses aliments parmi des alternatives appréciées de manière équivalente au cours d'un repas sur le plaisir de manger et la prise alimentaire associée. L'ensemble des travaux a porté sur des adultes (en bonne santé et de poids normal) dont l'effet du choix a été évalué parmi des aliments d'appréciation équivalente. La première partie de cette thèse a évalué deux caractéristiques d'un assortiment de desserts pouvant moduler l'effet du choix : (i) le degré de similarité entre des desserts et (ii) le niveau d'appréciation initial des desserts. Deux études comportementales suivant le même paradigme expérimental ont été menées chez des adultes (n=80 dans chaque étude) assistant à une séance de choix et une séance de non-choix. Si les notes d'appréciation des desserts étaient plus élevées en situation de choix que de non-choix quel que soit le degré de similarité entre les aliments, un effet du choix sur la prise alimentaire n'a été observé que lorsque les produits étaient suffisamment dissimilaires. Le niveau d'appréciation initial des desserts n'a pas modulé l'effet du choix. La deuxième partie de cette thèse a étudié l'impact du choix et/ou de la variété sur l'appréciation de légumes et la prise alimentaire associée à travers une étude comportementale où chaque participant (n=59) a assisté à chacune des conditions suivantes : (i) service d'une seule recette de légumes (non-choix/non-variété) ; (ii) service des trois recettes (non-choix/variété) ; (iii) choix d'une recette parmi trois (choix/non-variété) et (iv) choix d'autant de recettes souhaitées (choix/variété). Le choix et la variété augmentaient l'appréciation des légumes consommés mais seul un effet du choix a été observé sur la prise alimentaire. Aucun effet de synergie entre le choix et la variété n'a été observé sur l'appréciation des légumes ou la prise alimentaire. Ces travaux de thèse ont donc montré que donner à un adulte l'opportunité de choisir son aliment augmente l'appréciation de cet aliment, même si celui-ci porte sur des aliments appréciés de façon équivalente initialement. Cependant, l'effet du choix, comme de la variété, sur la prise alimentaire semblerait vulnérable à des facteurs de contexte et plus précisément le degré de similarité entre les aliments.