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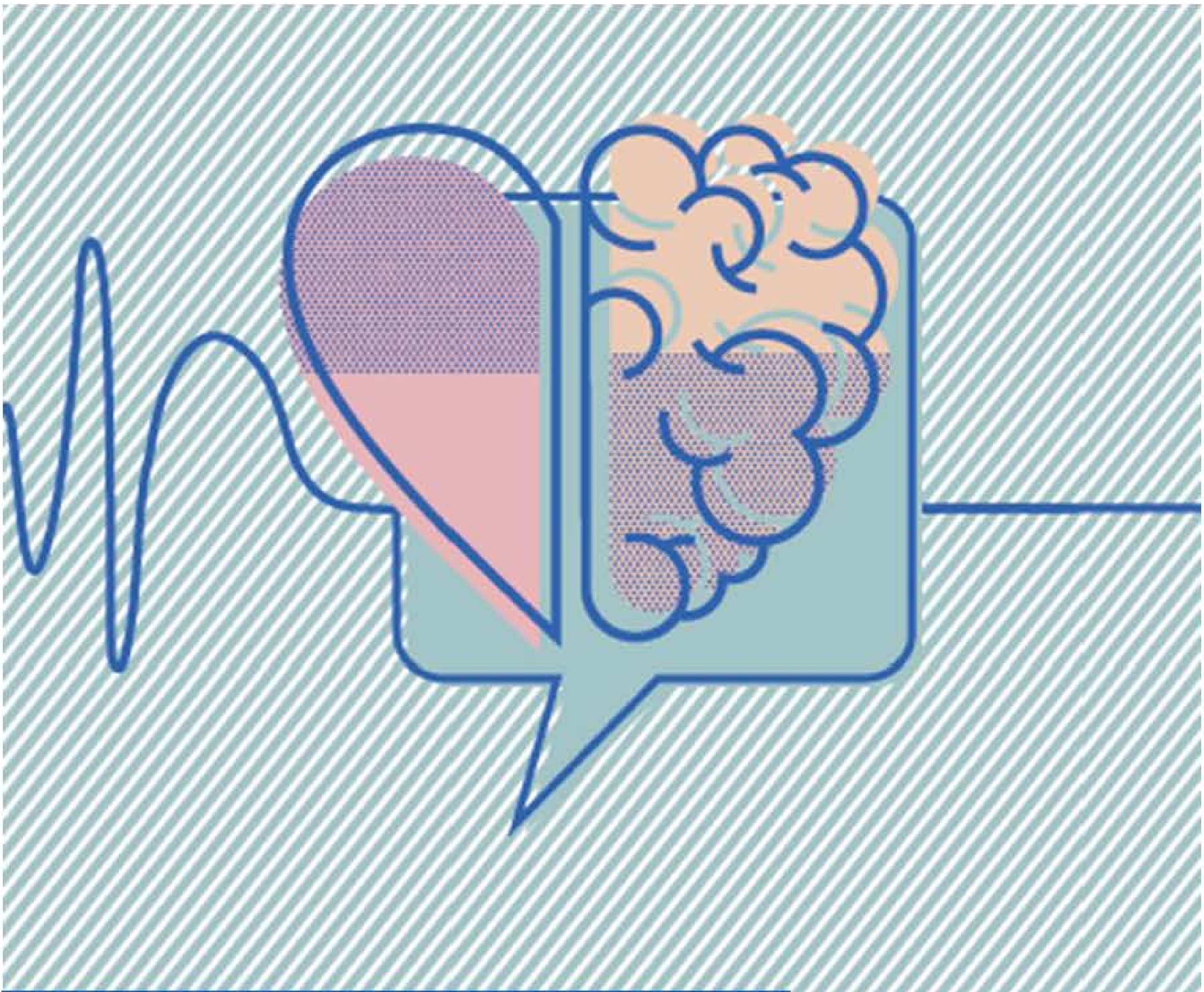

UNDERSTANDING CONSUMERS' FOOD EXPERIENCE THROUGH MEASUREMENT OF EXPLICIT AND IMPLICIT RESPONSES

Sofie Lagast

GHENT
UNIVERSITY

Follow
your
HEART
but
take
your
BRAIN
with
you

(Quote by Alfred Adler – founder of the school of individual psychology)

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UNDERSTANDING CONSUMERS' FOOD EXPERIENCE THROUGH MEASUREMENT OF EXPLICIT AND IMPLICIT RESPONSES

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Inzicht in de smaakbeleving van consumenten door het meten van expliciete en impliciete responsen

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AAP	Approach-Avoidance Procedure
ACQ	Attitude to Chocolate Questionnaire
ANOVA	Analysis of Variance
ANS	Autonomic Nervous System
CA	Correspondence Analysis
CATA	Check-All-That-Apply
CLT	Central Location Test
CNS	Central Nervous System
DEBQ	Dutch Eating Behavior Questionnaire
DF	Degrees of Freedom
ECG	Electrocardiogram
EEG	Electroencephalogram
EDA	Electrodermal Activity
EDR	Electrodermal Response
FAA	Frontal Alpha Asymmetry
HR	Heart Rate
HRV	Heart Rate Variability
ICA	Independent Component Analysis
ISO	International Organization Standardization
JAR	Just-About-Right
LSD	Least Significant Difference
M	Mean
PCA	Principal Component Analysis
RATA	Rate-All-That-Apply
SD	Standard Deviation
TDE	Temporal Dominance of Emotions
SDNN	Standard Deviation of all Normal-to-normal (NN) intervals
SE	Standard Error

Samenvatting

De sensorische evaluatie van voedingsproducten beperkt zich hoofdzakelijk tot de beoordeling van de algemene acceptatie als indicator voor de smaakbeleving van de consument. Het blijkt echter dat hoge acceptatie scores zich niet automatisch vertalen in hogere verkoop of consumptie. De gebruikelijke sensorische consumententesten zijn afhankelijk van de expliciete en zelf-gerapporteerde responsen van de consument om de acceptactie van een product te meten. Desondanks is het expliciet vragen naar de acceptatie van een product niet altijd een goede voorspeller is van consumptiegedrag. We weten met andere woorden niet (altijd) wat we lekker vinden. Als antwoord hierop kan acceptatie verder ontleed worden in een expliciet en impliciet niveau. Beide niveaus refereren naar de hedonische impact van voeding na consumptie, maar verschillen in het gewaarwordingsniveau van de consument: bewust vertaald of expliciet en onbewust of impliciet.

De smaakbeleving van de consument is een non-rationeel en intuïtief proces en acceptatie alleen is bijgevolg niet representatief voor de volledige smaakbeleving van de consument. Een manier om op het non-rationele en intuïtieve karakter in te spelen is het bestuderen van emotionele associaties met voedingsproducten. Ook hier is de belangrijkste uitdaging die onderzoekers ondervinden het accuraat meten van deze emotionele associaties. Wederom worden emotionele associaties hoofdzakelijk via expliciete, zelf-gerapporteerde en verbale responsen gemeten. In recent onderzoek werden deze emotionele associaties ook op een expliciet non-verbale manier gemeten en heel recent schoof de aandacht ook op naar het meten van impliciete responsen van deze emotionele associaties door neurofysiologische technieken.

Dit doctoraatsonderzoek heeft als doel het bestuderen van het brede veld van metingen die gebruikt worden om de smaakbeleving van de consument beter te begrijpen. Als eerste omhelst dit onderzoek zowel het bewuste of expliciete en onbewuste of impliciete niveau. Het onderzoek bekijkt de methodes in sensorisch consumentenonderzoek voor acceptatie én emotionele associatie en heeft oog voor zowel de gebruikelijke expliciete, zelf-gerapporteerde methodes als voor de innovatieve, interdisciplinaire impliciete methodes.

De eerste onderzoeksdoelstelling bestond uit het toereiken van een uitgebreid overzicht van de methodes om emotionele associaties gerelateerd aan voeding te meten. Het systematisch bestuderen van de literatuur toonde een dominantie van expliciete over impliciete en gecombineerde methodes aan en identificeerde de recente trend van impliciete methodes als een opkomende interdisciplinaire tool.

De tweede onderzoeksdoelstelling beoogde het onderzoeken van de expliciete responsen van consumenten na consumptie van voedingsproducten. Naast consumentenacceptatie werden zowel verbale als non-verbale expliciete metingen van emotionele associaties gerelateerd aan voeding onderzocht. De resultaten toonden aan dat het mogelijk was aan de hand van expliciete verbale en non-verbale emotionele associaties verschillende pure chocolades van elkaar te onderscheiden. Dit ondersteunt de toegevoegde en unieke informatie van deze emotionele associaties gerelateerd aan consumptie van voedingsproducten en geeft nieuwe informatie dat in productontwikkeling kan gebruikt worden.

Als derde onderzoeksdoelstelling werd vooropgesteld om impliciete responsen van consumenten tijdens de consumptie van voedingsproducten te bestuderen. Het bleek mogelijk om via responsen van het autonome zenuwstelsel, zoals hartslag en huidgeleidingsactiviteit, een onderscheid te maken tussen de smaakprikkels. Bijgevolg dragen de responsen bij tot de emotionele associaties met voedingsproducten. Geen significante verschillen werden gevonden voor frontale alfa-asymmetrie. Verder onderzoek is nodig om de manier waarop frontale alfa-asymmetrie bijdraagt tot consumenten acceptatie te begrijpen.

De belangrijkste wetenschappelijke bijdrages van dit doctoraatsonderzoek zijn (1) het in kaart brengen van de meetmethodes van emotionele associaties met voedingsproducten op een systematische manier, (2) het bestuderen van acceptatie en emotionele associaties met voeding via zowel expliciete als impliciete responsen, (3) de nieuwe inzichten verkregen door het onderzoeken van de relatie tussen sensorische aspecten en expliciete emotionele associaties gebaseerd op verbale en non-verbale profilering, en (4) de methodologisch innovatieve implementatie van neurofysiologische metingen als methode om impliciete responsen te meten in sensorische evaluatie door het uitvoeren van het eerste experimentele onderzoek bij consumenten om de invloed van geaccepteerde en niet-geaccepteerde voedingsproducten op de neurofysiologische responsen te bestuderen.

Dit doctoraatsonderzoek bevestigt het belang van het meten van zowel expliciete als impliciete responsen in sensorische evaluatie van voedingsproducten om een beter begrip van de smaakbeleving van de consument te verkrijgen. Dit onderzoek toont aan dat er duidelijke opportuniteiten zijn voor het meten van impliciete responsen in sensorische evaluatie van voedingsproducten. De rol van toekomstig onderzoek bestaat erin om het meten van impliciete responsen in sensorische onderzoek uit te breiden, te ijken en te vertalen naar praktisch inzetbare methodes.

Summary

The sensory evaluation of food products is often limited to the assessment of overall acceptance as an indicator of the consumers' food experience. However, it has become clear that high acceptance scores don't automatically result in more sales nor higher consumption. Common sensory consumer tests use self-reported measures to assess consumer acceptance of food products. Although these tests provide valuable insights and have attributed tremendously to sensory science, explicitly asking a consumer about overall acceptance of a food product is likely to suffer from social desirability and self-representation biases. To overcome these biases, acceptance or liking can be further classified into an explicit and implicit level. Explicit and implicit liking both refer to the hedonic impact during consumption, but differ in terms of consciousness for the consumer: conscious awareness or explicit or unconscious awareness or implicit.

As the consumers' food experience is a non-rational and fast intuitive process rather than a slow reasoning process, acceptance measurement alone does not cover the consumers' total food experience. One way to deepen the understanding of the consumers' food experience is to examine consumers' food product-elicited emotions. Despite efforts to better understand the consumers' experience by integrating emotions, the major challenge food researchers still encounter in studying emotional responses elicited by food products is how to accurately measure food product-elicited emotions as sensory research on emotions mainly depend on explicit, self-reported and verbal responses. In very recent response to this, explicit non-verbal responses are measured and also increasing attention has been paid to the measurement of implicit responses through neurophysiological techniques to examine the food product-elicited emotions.

This doctoral dissertation aimed to better understand consumers' food experience by looking at the wide field of measures and is the first to comprise both the explicit and the implicit responses. The research started with explicit self-reported responses traditionally used in sensory consumer research and moved beyond these self-reported measures by examining implicit responses of food product acceptance and food product-elicited emotions.

The first research objective consisted of providing a comprehensive overview of measurements of food product-elicited emotions in sensory consumer research. The systematic review revealed a dominance of explicit over implicit or combined methods and identified the recent trend of implicit methods as an emerging interdisciplinary tool.

The second research objective pertained to the measurement of consumers' explicit responses to food products. Both verbal and non-verbal measures of explicit food product-elicited emotions together with consumers' acceptance were investigated. Explicit verbal and non-verbal emotional conceptualizations were able to discriminate between dark chocolates. The results support the added and unique information of emotional responses to food, which can give new information for product development.

The third research objective was to examine the measurement of consumers' implicit responses to food products. Responses of the autonomic nervous system, heart rate and electrodermal activity, were able to discriminate between the taste stimuli and contribute to food product-elicited emotion. Frontal alpha asymmetry on the other side showed no significant differences. The manner how frontal alpha asymmetry contributes to food product acceptance still needs further research.

The major research contributions of this doctoral dissertation refer to (1) the first systematic review on food product-elicited emotions providing an exhaustive overview of the methods, measurements and instruments that are currently applied in sensory consumer research, (2) the inclusion of both explicit and implicit responses to examine subjective food product quality and food product-elicited emotions, (3) new insights on the interrelation between the sensory aspects and the explicit food product-elicited emotions based on verbal and non-verbal emotional conceptualization profiling, and (4) the methodological innovative implementation of neurophysiological measures as a measurement of implicit responses in sensory evaluation by conducting the first experimental sensory consumer research to study the influence of tasting liked and disliked food products on consumers' neurophysiological responses.

This doctoral research supports the added value of the measurement of implicit responses to explicit responses in sensory evaluation of food products to obtain a better understanding of the consumers' food experience. Future research should expand on these methods by optimizing, standardizing and validating the measurement of implicit responses to food products. Benchmarking these methods and comparing them with explicit measures can yield positive results in understanding the consumers' food experience as this doctoral research has indicated that there are clear opportunities and gains in the field of the measurement of implicit responses of acceptance and food product-elicited emotions.

PART I:
GENERAL INTRODUCTION

Chapter 1
Introduction

This introduction first presents the rationale of this doctoral dissertation. Next, it includes a description of the conceptual framework, the related research objectives and research questions and research design. Finally, the intended research contribution and the structure of the doctoral thesis are provided.

1.1 Rationale of the doctoral dissertation

The whole food experience is driven by a multitude of factors, which are unique for every individual. The environment, social interaction, physiological outcome and the sensory experience with the food have been identified as the main factors influencing the total experience (Piqueras-Fiszman & Jaeger, 2015; Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017a). This dissertation will focus on the last factor which has only recently gained increasing scientific interest: the understanding of the consumers' experience with food.

Understanding consumers' food experience is a complex field which involves many stakeholders. Not only food companies have studied food products in the last decades, also scientists have researched food and the food experience. Many different disciplines, ranging from food science and technology to nutrition, biochemistry, physiology, psychology and marketing (Cardello, 1994), have invested time and effort in understanding the consumers' experience. In food research, the scientific discipline that studies the acceptance of consumer products and human evaluation of consumer products by the senses (taste, sight, smell, touch and hearing) is called sensory analysis (Lawless & Heymann, 1998).

A key term in sensory analysis regarding consumer testing is **acceptance,** as an indicator of the consumers' experience. Acceptance measurement assesses the consumer's appeal of food, the degree of liking or disliking of a food product (Lawless & Heymann, 2010). In sensory research, product acceptance is generally measured by determining the hedonic value or overall liking (Lawless & Heymann, 2010). This is traditionally performed by asking the consumer to indicate their overall liking on a, e.g. 9-point, hedonic scale upon consumption of a food product (appendix A). Common sensory consumer tests rely thus on **explicit, self-reported responses** to measure the consumer's acceptance of food products. These tests require conscious information processing and correct verbalization of the experienced sensory modalities, such as flavor, aroma or appearance and texture.

However, it has become clear that high acceptance scores don't automatically result in more sales nor consumption. Despite high acceptance scores on a large number of sensory and consumer tests before market introduction, there remains a high failure rate (up to 80%) among all new food products when introduced in the marketplace (Köster, 2012; Ryynänen & Hakatie, 2014; van Kleef, van Trijp, & Luning, 2005). Thus, high acceptance scores do not always predict subsequent consumption as reflected in sales (Rudolph, 1995). Furthermore, explicitly stated overall acceptance explains only a part of variation in consumption (de Castro & Plunkett, 2001). This demonstrates that explicitly asking a consumer about overall acceptance of a food product may not always be predictive for behavior or simply put: we do not (always) know what we like (Veldhuizen, 2010).

One lead to overcome this problem was given by Berridge and Robinson (2003). They proposed that acceptance or liking can be further classified into an explicit and implicit level. Both **explicit and implicit liking** refer to the hedonic impact during consumption. Yet, they differ in terms of explicitness or implicitness (Pool, Sennwald, Delplanque, Brosch, & Sander, 2016). The consumer can have a physical longing for something (Pavlovian system) without being cognitively aware, but also the reverse is true: a consumer can think they want something without having a bodily craving (a cognitive desire – goal-directed system). Additionally, the core processes of liking are different from explicit self-report on those processes as consumers are cognitively aware of the act of eating but remain unaware of the underlying processes that cause certain eating behavior patterns (Berridge, 1996, 2009). The intensity of impulses toward food or rejection of food can be studied through measurement of the **approach and avoidance motivational tendencies** (Piqueras-Fiszman, Kraus, & Spence, 2014). Implicit measures of these motivational tendencies has been performed by use of the approach-avoidance procedure (AAP). Very recently, these motivational tendencies have been studied through the use of electroencephalogram (EEG) in food research (Brouwer, Hogervorst, Grootjen, van Erp, & Zandstra, 2017; Walsh, et al., 2017a).

However, acceptance measurement alone does not cover the consumers' food experience as it is a non-rational process and actual food choices are often governed by a fast intuitive process rather than by a slow reasoning process (Dalenberg, et al., 2014; Kahneman, 2003; Köster, 2009; Köster & Mojet, 2015). One way to deepen the understanding of the consumers' food experience and to anticipate on the non-rational and intuitive nature is to examine **consumers' emotional associations** (Gutjar, et al., 2015b; King, Meiselman, & Carr, 2013; Köster & Mojet, 2015; Meiselman, 2015; Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017b). Empirical evidence shows that consumers' emotional associations with food products can add additional information beyond overall acceptance (Cardello, et al., 2012; Gutjar, et al., 2015b; King & Meiselman, 2010; Ng, Chaya, & Hort, 2013; Schouteten, et al., 2015a; Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014; Thomson, Crocker, & Marketo, 2010) and even significantly improve food choice prediction (Dalenberg, et al., 2014; Gutjar, et al., 2015a).

The effect of emotional responses to, for example food acceptability, intention to purchase, food choice, attitudes or behavior, has been examined in various ways (Walsh, et al., 2017a; Wardy, Sae-

Eaw, Sriwattana, No, & Prinyawiwatkul, 2015). Most research on emotions in food research literature focuses on discriminating between products with high acceptance levels, using traditional measures of **explicit, verbal and self-reported responses** (Köster & Mojet, 2015). The most common approach is an emotional lexicon, which is a questionnaire format with a list of emotional terms that can be checked (e.g. check-all-that-apply, CATA) or rated (e.g. rate-all-that-apply, RATA or 5-point rating scale) (Appendix A).

Yet, limitations and problems in these measurements of emotional associations in response to food have been identified. First and for most, research on emotions in food research is mainly done in a verbal self-reported way. Some consumers consider using certain words to describe how they feel rather strange as reported by Jaeger, Cardello, and Schutz (2013) and some consumers select emotional terms even if they are not really experiencing them before, during or after consumption (Thomson & Crocker, 2015). Furthermore, cultural differences in emotional perception and experience can also be problematic in these measurements (van Zyl & Meiselman, 2015, 2016). Thirdly, a well-known difficulty of the emotional lexicon is the translation problem. When translating emotional terms meaning is lost, which makes it hard to apply them in a multicultural setting. This has led to an increasing interest in non-verbal self-reported measurements.

In an effort to bypass these problems, researchers have come up with more visual representations of the emotions. **Explicit non-verbal self-reported** instruments, such as Product Emotion Measurement Instrument (PrEmo, Appendix A), can easily circumvent the translation problem (Köster & Mojet, 2015) as translation is not necessary. And although the scoring happens more intuitively, consumers might not seem very familiar with these pictograms and possibly uncertain about the meaning of the graphical representations (Jaeger, et al., 2017a). A possible solution lies in the use of emoji, which have been suggested as a more familiar alternative to capture the explicit non-verbal emotions elicited by food products (Jaeger, Vidal, Kam, & Ares, 2017b).

Sensory research on emotions is mainly done through measurement of explicit and self-reported responses. And despite the efforts to better understand the consumers' experience by integrating emotions, still the major challenge food researchers encounter in studying emotional associations elicited by food products is how to accurately measure them (Samant, Chapko, & Seo, 2017).

Studies confirm major limitations and problems of explicit measures of food product-elicited emotion. First, explicit measures run the risk of being influenced by the participant, which may for example affect the validity of the emotional assessment (Danner, Sidorkina, Joechl, & Duerrschmid, 2014b; de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012). Second, social desirability and self-representation biases can similarly influence the explicit self-reported measures of emotion (Chai, et al., 2014; Schwarz & Oyserman, 2001). Third, explicit measures are to some degree retrospective as emotions are elicited after the experience (Danner, Haindl, Joechl, & Duerrschmid, 2014a). Fourth, some participants can lack the introspective capacity to correctly identify, recognize and then verbalize the perceived emotion (Köster, 2003; Nisbett & Wilson, 1977). As a result stated behavior does not correspond to actual behavior and consequently, these explicit measures run the risk of being biased and subjective (de Wijk, et al., 2012).

In an effort to address the problems of explicit measures of food product-elicited emotion, increasing attention has been paid to **implicit measures** to assess the consumers' emotional associations. Unlike explicit measures which are characterized by processes which are intentional, controlled, effortful and slow, implicit measures reflect outcomes that rely on processes which are unintentional, uncontrolled, efficient and fast (De Houwer, 2006; De Houwer & Moors, 2007; Köster & Mojet, 2015).

Interdisciplinary research (psychology, food science and medical science) has created new approaches to measure **food product-elicited emotion** in an **implicit** manner (Walsh, et al., 2017b) through expressive, implicit behavioral task and physiological measures (Lamote, Hermans, Baeyens, & Eelen, 2004). First approach is measuring the **expressive reactions**, such as facial expression, that accompany emotion (Desmet, 2003; Ekman, 1993; Ekman & Friesen, 1971). Second approach is to register reaction time through the **implicit behavioral task measures**, such as the affective priming paradigm (APP) (Klauer, Musch, Musch, & Klauer, 2003). The third approach is to measure **physiological changes** in the body, such as cardiovascular responses (i.e. heart rate, heart rate variability, blood pressure), respiratory responses (i.e. respiration rate), electrodermal responses (i.e. skin conductance response, skin conductance level) and pupillary responses (i.e. pupillary reflex) (Kreibig, 2010; Mauss & Robinson, 2009). Yet, as these implicit methods, particularly the physiological measures, have only been limitedly applied in consumer and sensory research, their value is yet to be determined (Mojet et al., 2015).

This doctoral dissertation aims to look at the wide field of measurements of consumers' food experience and is the first to comprise both the **explicit** and the **implicit** responses. It starts at explicit self-reported measures traditionally used in sensory and consumer research and aims to move beyond the reliance of these measures by examining implicit responses of food product acceptance and food product-elicited emotion. Four different ways to measure the consumers' food experience are examined in this dissertation: (1) traditional, explicit verbal measures, (2) explicit, non-verbal measures, (3) implicit measures of approach-avoidance motivational tendencies and (4) implicit measures of neurophysiological emotional responses to food products.

1.2 Conceptual framework

The conceptual framework of this doctoral dissertation (Figure 1.1) combines both the explicit and the implicit level of consumers' food experience by extending, expanding and integrating existing models and current theories. The conceptual framework aims to illustrate the presence of both an explicit and implicit level of the consumers' food product experience to obtain a better understanding of the overall food experience. By incorporating theories and approaches from psychology, neuroscience, neuro- and psychophysiology, human biology, food research and consumer and sensory research, this framework illustrates the multidisciplinary perceptive on the consumers' food experience.

The conceptual framework consists of two key concepts being addressed below: **food quality perception** (1.2.1) and **food product-elicited emotions** (1.2.2). First the concept of food quality perception is defined, with specific attention for objective and subjective food product quality. Second, the concept of food product-elicited emotions is explained. Each concept is analysed on both the **explicit** and **implicit** level of the conceptual framework.

For the **explicit** level, the conceptual framework draws on the consumer quality perception process (Fernqvist & Ekelund, 2014; Grunert, Larsen, Madsen, & Baadsgaard, 1996; Steenkamp, 1990) and is extended with the influence of food product-elicited emotions (Gutjar, et al., 2015a; Thomson & Crocker, 2015). These theoretical concepts are commonly used in research on consumers' quality perceptions and cover the explicit level of the consumers' food experience.

In this conceptual framework the explicit level has been expanded with an implicit level of the consumers' food experience. The **implicit** level falls back on the integration of the central nervous system in models of food-related behaviors (Cardello, 1994; Smeets, Charbonnier, van Meer, van der Laan, & Spetter, 2012) and is based on theories of emotional processing (Kreibig, 2010; Mauss & Robinson, 2009) and the theory of approach-avoidance behavior (Davidson, 2004).

This doctoral dissertation uses the terminology of explicit and implicit measures as defined by De Houwer and Moors (2007). According to De Houwer and Moor (2007) the term measure can refer either to the measurement procedure or a measurement outcome. A measurement outcome is meant to reflect a certain construct, such as attitudes or in this case acceptance or liking. Whereas, a measurement procedures can be described as direct or indirect. In direct measurement procedures the participants are asked to self-assess the to-be measured construct and in indirect measurement procedures, the construct is assessed indirectly on the basis of other behavior. Explicit or implicit measures in this doctoral thesis are referring to a measurement outcome.

De Houwer (2006) also suggested to view the concept implicit as a synonym for the concept automatic. The concept automatic is defined in terms of a set of features such as unconscious, uncontrolled, unintentional, efficient and fast. Moreover, the term automatic and its features are usually applied to describe the nature of processes. Hence, it can also be used to characterize the processes that underlie measurement outcomes. This means that automatic processes operate even when people are not conscious of the processes and do not have the intention to engage in these processes, that the operation of the processes cannot be controlled, and that the processes operate even when cognitive resources are scarce and time is limited. Non-automatic processes on the other hand are conscious, intentional, controlled, effortful, and slow. This refers to the fact that these processes operate only when people are consciously aware of them and have the intention to engage in these processes, that the operation of these processes can be controlled, and that the operation of these processes depends on the availability of cognitive resources and time.

Based on this conceptual analysis De Houwer and Moors (2007) defined an implicit measure as:

> *"An implicit measure is a measurement outcome that reflects the to-be-measured construct by virtue of processes that are uncontrolled, unintentional, goal independent, purely stimulus driven, autonomous, unconscious, efficient or fast. "*

This definition and conceptual characterization is applied throughout the whole doctoral dissertation.

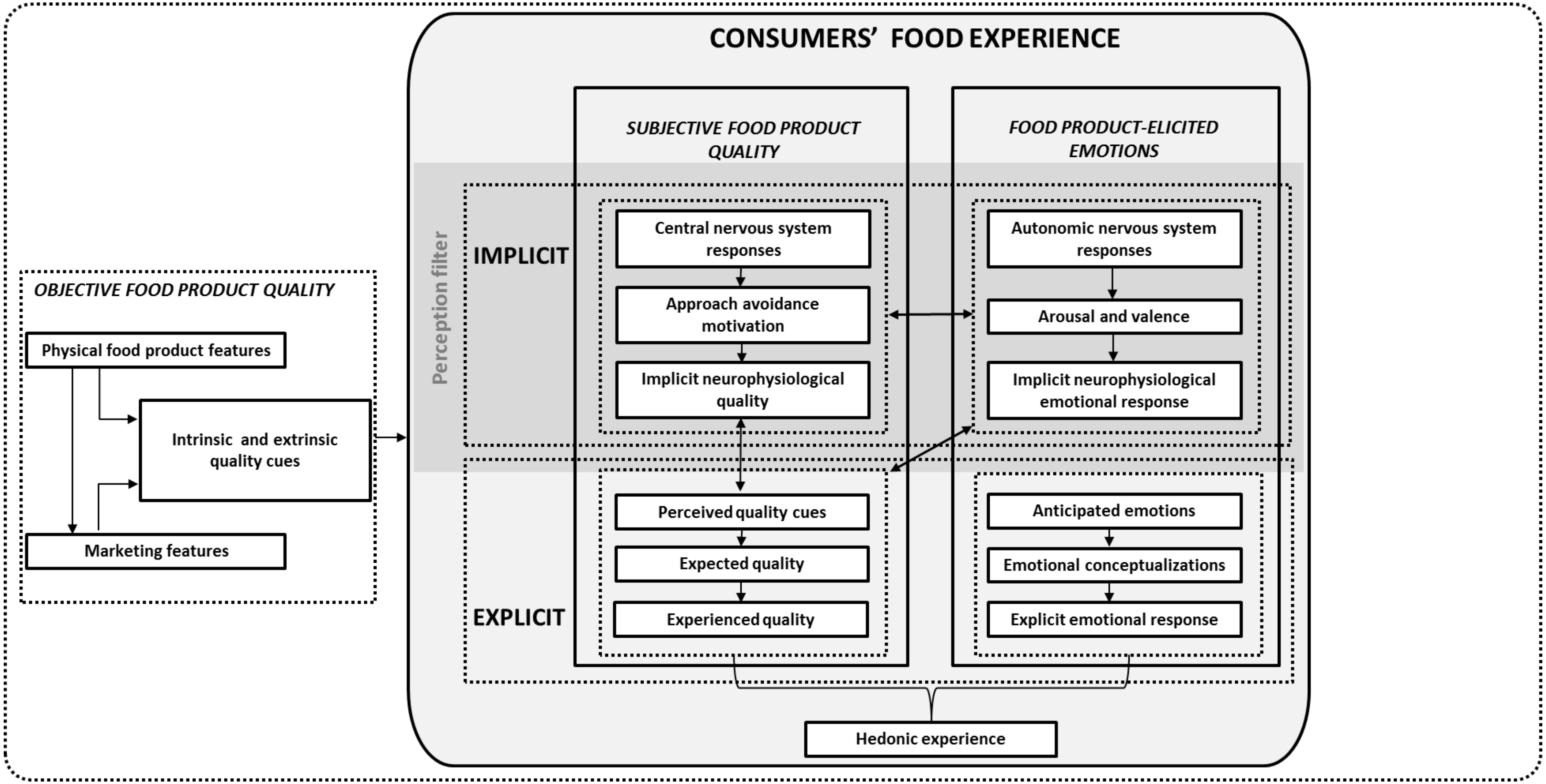

Figure 1. 1 Conceptual framework
(Cardello, 1994; Davidson, 2004; Fernqvist & Ekelund, 2014; Grunert, et al., 1996; Gutjar, et al., 2015a; Kreibig, 2010; Mauss & Robinson, 2009; Smeets, et al., 2012; Steenkamp, 1990; Thomson & Crocker, 2015).

1.2.1 The concept of food quality perception

The concept of food quality perception consists of two connected parts which are separated by the perception filter (Risvik, 2001). The overall perceived quality of a food product is on the one hand influenced by the objective food product quality (Grunert, et al., 1996). On the other hand there is the subjective food product quality, the perceived quality of the objective quality by the consumer.

The **objective food product quality** refers to the technical, instrumental and objectively measurable and verifiable nature of food products and processes. The **physical product features** cover the physicochemical characteristics intrinsic to a food product (e.g. sugar content) and will form the **intrinsic quality cues**. These intrinsic quality cues such as the sensory attributes (e.g. color, texture, aroma, etc.) and microstructural characteristics (e.g. ingredients) are thus inherent to a food product. These sensory attributes and microstructural characteristics can be determined by use of instrumental measurements (Oude Ophuis & Van Trijp, 1995). Based on the physical product features food companies will set the **marketing features** which will cover the **extrinsic quality cues** of a food product (Oude Ophuis & Van Trijp, 1995). These external quality cues present aspects of the products that are not physically part of the food product such as brand, price and packaging information.

This conceptual framework has expanded the notion of **subjective food product quality,** the way consumers perceive the food product quality, which can be significantly different from the objective food product quality (Grunert, 2005), by splitting it in two lower level concepts: **explicit** and **implicit** subjective food product quality. The distinction made in the conceptual framework links back to the distinction between explicit liking and implicit liking noted by Berridge and Robinson (2003). Just like in explicit and implicit liking, explicit and implicit food product quality both refer to the hedonic impact during consumption and simply differ in terms of explicitness or implicitness (Pool, et al., 2016). Below the two terms, are further explained.

Subjective food product quality at the explicit level

The subjective food product quality at the explicit level refers to the perception of food products. Key to a perception is that it can be reported explicitly by the consumer. It represents the way consumers consciously perceive the food product quality. The subjective food product quality at the explicit level consists of three main components that influence the consumers in their final choice: (1) the **perceived quality cues**, (2) **the expected quality** and (3) **the experienced quality**. When first perceiving a product, consumers will gather (perceived quality) cues based on the intrinsic and extrinsic quality cues of the objective food product quality. Based on these cues, consumers build expectations, the expected quality. When consumption occurs, the expected quality is confirmed or disconfirmed and as such the experienced quality is determined (Deliza & MacFie, 1996).

Sensory science studies the experienced intrinsic and extrinsic quality cues through sensory consumer tests. In sensory research food product quality is generally measured by assessing the hedonic value (Lawless & Heymann, 2010; Meiselman, 2013). This is traditionally performed by instructing consumers to indicate their overall liking on a 9-point hedonic scale. These explicit measurements are still core in sensory science (Lawless & Heymann, 2010). Yet this doctoral thesis has the aim to contribute to a broader understanding of the consumers' experience by expanding the self-reported measurements with the implicit measurement. Therefore the subjective food product quality should also be determined at an implicit level.

Subjective food product quality at the implicit level

The subjective food product quality at the implicit level refers to the sensations caused by food products. Key to a sensation is that consumers cannot per se report explicitly on the sensation. A sensation is a passive process that brings information from the outside world to the body and the brain. Yet, through implicit measures, sensations can be assessed.

Processing of the information from a sensory stimulus is explained in three steps. First, during consumption of food, the physicochemical characteristics interact with the human sensory receptors and are converted into a nervous signal which is sent through various nervous tracts to the **central nervous system**. Second, if a threshold is reached the signal is transformed into a sensation of the food product's taste, flavor, aroma, texture, auditory, appearance and will be represented in the brain (Cardello, 1994). Third, the brain integrates the information using past experiences, memories and will transform the sensation into a perception (Haese, Humeau, De Oliveira, Le Callet, & Le Cloirec, 2014; Meilgaard, Carr, & Civille, 2006).

The overall liking of the food product is also first passively, non-consciously processed in the brain before it becomes explicit for the consumer based on the previously explained process. Neurophysiological measures are able to go back up to the perception process and register responses before the cognitive processing of the information (Haese, et al., 2014). The prefrontal cortex is of particular interest for hedonic and motivational processing (Coan & Allen, 2004; Davidson, 2004). The prefrontal cortex functions as a convergence zone and includes other interconnected structures such as the anterior cingulate, amygdala, hippocampus and insula. These structures are organized in two large motivational systems: the approach system and the avoidance or withdrawal system. The **approach system** facilitates appetitive behavior and is described as a generator of positive affect. The

avoidance system facilitates moving away from an aversive stimulus (Davidson & Irwin, 1999; Davidson, Jackson, & Kalin, 2000; Silva, Pizzagalli, Larson, Jackson, & Davidson, 2002). The main theory on hemispheric lateralization is the valence hypothesis, which states that the left hemisphere is specialized for positive stimuli and approach and the right hemisphere is dominant for negative stimuli and avoidance (Borod, 1992; Davidson, 2004; Davidson, et al., 2000). Hemispheric asymmetry scores (comparing the right to the left activity) of the alpha band frequency (8-13Hz) are of particular interest as positive frontal alpha asymmetry (FAA) is reported for positive stimuli and negative frontal alpha asymmetry (FAA) for negative stimuli (Briesemeister, Tamm, Heine, & Jacobs, 2013). This brain activation in response to consumption of food products refers to the **implicit neurophysiological quality** in the conceptual framework.

Although FAA is well documented in other research fields (for a review see Harmon-Jones, Gable, and Peterson (2010) and Briesemeister, et al. (2013)), it has only very recently been explored in food research (Brouwer, et al., 2017; Harmon-Jones & Gable, 2009; Walsh, et al., 2017a; Walsh, et al., 2017b). Most of these studies used visual stimuli, such as videos of food concerns (safety, hygiene and spoilage) (Walsh, et al., 2017b), breakfast meal videos (Walsh, et al., 2017a) or pictures of desserts (Harmon-Jones & Gable, 2009).

1.2.2 Food product-elicited emotion

The hedonic experience is not only driven by overall food product quality perception but also by the consumers' emotional responses elicited by food products, the **food product-elicited emotions**. These emotions are important to understand the consumers' food experience.

Food product-elicited emotions are described as a brief but intense physiological and/or mental reaction to a product (Bagozzi, Gopinath, & Nyer, 1999; Kenney & Adhikari, 2016; King & Meiselman, 2010; Samant, et al., 2017). The food product-elicited emotions are generally positive or neutral, which aligns to the general idea that food evokes positive emotions (hedonic asymmetry) (Desmet & Schifferstein, 2008; Gibson, 2006; King & Meiselman, 2010). Recent studies have attempted to find the association of consumers' acceptance and food product-elicited emotions (for a review, Jiang, King, and Prinyawiwatkul (2014); Kenney and Adhikari (2016); Köster and Mojet (2015); Lagast, Gellynck, Schouteten, De Herdt, and De Steur (2017)). Similarly to subjective food product quality, a distinction is made between **explicit** emotional responses (mental response or conceptualization) and **implicit** emotional responses (neurophysiological response).

Food product-elicited emotion at the explicit level

The food product-elicited emotion at the explicit level refers to the non-automatic processes or conceptualizations of consumers. Key to non-automatic process is that it is conscious, intentional, controlled and slow (De Houwer, 2006). It represent the way consumer consciously perceive the emotional responses elicited by the food product.

Upon consumption the perceived quality cues will lead to **anticipated emotions** of food products, emotions a consumer expects to experience during consumption (De Pelsmaeker, et al., 2017). Expected emotions are shown to influence and mediate behavior (Macht & Dettmer, 2006) and influence the **emotional conceptualizations** (Thomson & Crocker, 2015). Emotional conceptualizations are measured through self-reported measures like emotional lexicons (e.g. the EsSense Profile® by King and Meiselman (2010)) which are commonly used in consumer and sensory research. The self-reported measures rely on the conscious responses of the consumer and are therefore **explicit emotional responses**.

In sensory research, the role of emotion has been increasingly acknowledged (Johnson & Stewart, 2005). Recent studies show that consumers' emotional conceptualizations towards food products can provide additional information beyond overall acceptance (Cardello et al., 2012; Coleman, Miah, Morris & Morris, 2014; Gutjar et al., 2014; King & Meiselman, 2010; Ng, Chaya, & Hort, 2013; Schouteten et al., 2015a; Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014; Thomson et al., 2010).

Moreover, inclusion of emotional conceptualization profile next to sensory profile significantly improves the prediction of consumers' food product choice behavior (Dalenberg et al., 2014). Traditionally emotional conceptualization are assessed by explicit verbal self-reported measures, such as an emotional lexicon (Gutjar, et al., 2015a). Whereas several studies examined emotional conceptualizations of food products, it is much more challenging to examine the implicit emotional response to food products. This why this doctoral thesis has added an implicit level of food product-elicited emotion.

Food product-elicited emotion at the implicit level

The food product-elicited emotion at the implicit level, refers to the neurophysiological response caused by food products. Key to a neurophysiological response is that consumers do not possess control over the response (involuntary) and that these responses happen automatically.

The processing of emotional stimuli, such as liked and disliked food, activates the **autonomic nervous system** (ANS). ANS measures can be used as indicators of emotional response (Kreibig, 2010) measuring level of **arousal and valence** (Fernández, et al., 2012). Those measures of arousal and valence are indicators of the **implicit neurophysiological emotional response**. To register the neurophysiological changes that are accompanied by emotion, a variety of techniques is applied. Examples of these measures are heart rate, heart rate variability and electrodermal responses. As these measures cannot be manipulated or controlled by the consumer, they are considered as an implicit and objective measurement (Desmet, 2002). These measures also have the advantage that they do not disturb consumers during the emotional experience. Despite their advantages, these methods have only been limitedly applied in consumer and sensory research. Possible reasons are the complexity of those measures and that these measures are very time consuming.

The most commonly assessed parameters of ANS activation in emotional research are cardiac and electrodermal responses (Kreibig, 2010; Mauss & Robinson, 2009). Furthermore, a study of Rousmans, Robin, Dittmar, and Vernet-Maury (2000) found that responses cardiac and electrodermal responses were the most relevant ANS parameters to discriminate among different basic taste solutions and that these differences were associated with the hedonic valence. Yet, other studies applying ANS measurements in sensory science has shown inconsistent results. de Wijk, et al. (2012) for example did not find significant differences in heart rate (HR) for liked and disliked foods. Brouwer, et al. (2017) on the other hand found higher heart rates for chicken (liked) compared to mealworms (disliked) when participants were exposed to, frying and tasting the products, but only when chicken was presented first. Heart rate for breakfast drinks in the study of de Wijk, He, Mensink, Verhoeven, and de Graaf (2014) showed a positive association between heart rate and liking, whereas Danner, et al. (2014a) reports a lack of correlation in their study on different juices. Regarding electrodermal responses, de Wijk, et al. (2012) showed that disliked foods resulted in increased skin conductance responses and decreased finger temperature. Brouwer, et al. (2017) noted higher electrodermal activity for 'disliked' mealworms when participants were exposed to the mealworms and during cooling of the mealworms. Although these inconsistent results in consumer and sensory research, implicit measurement of emotion merit attention and further research.

1.3 Research objectives and research questions

The overall objective of this doctoral dissertation is to examine both explicit and implicit consumers' responses contributing to a better understanding of the consumers' food experience.

The research objectives correspond to the three main parts of the dissertation. In total four research questions and twelve subquestions are formulated in line with the conceptual framework described in the previous section. Each of these questions is addressed and answered in the three corresponding parts of this dissertation. An overview of the research objectives and research questions is provided in Table 1.1.

PART I: General introduction

Research objective 1: to provide a comprehensive overview of measurements of food product-elicited emotion in sensory and consumer research

The research chapter (chapter 2) in part I of this doctoral thesis looks into the measurement of food product-elicited emotion. The rising attention to emotion in consumer and sensory research has led to the introduction of many emotional instruments to capture consumers' emotions elicited by food (Dalenberg, et al., 2014). Although there is a wide variety in these measurements, a systematic review of these current measurements is lacking. Therefore, the first research question and subquestions ask:

Research question 1: What measurements are used in sensory and consumer research to assess consumers' food product-elicited emotion?

RQ1a How is food product-elicited emotion measured in sensory and consumer research?

RQ1b What type of products are used for measurement of food product-elicited emotion?

RQ1c How do the sample descriptives (sample size, age groups, gender) of the studies differ for each method?

Table 1. 1 Overview research objectives and corresponding research questions

Research objectives	Research questions
1: Provide a comprehensive overview of measurements of food product-elicited emotion in sensory and consumer research	*RQ1* *What measurements are used in sensory and consumer research to assess consumers' food product-elicited emotion?* *RQ1a* *How is food product-elicited emotion measured in sensory and consumer research?* *RQ1b* *What type of products are used for measurement of food product-elicited emotion?* *RQ1c* *How do the sample descriptives (sample size, age groups, gender) of the studies differ for each method?*
2: Examine consumers' acceptance and explicit verbal and non-verbal emotional conceptualization profile of dark chocolates	*RQ2* *How does a more positive, explicit verbal emotional conceptualization profile discriminate between dark chocolates?* *RQ2a* *How do the overall liking scores and the sensory profiles differ for dark chocolates with two low-calorie sweeteners in relation to dark chocolate with sugar?* *RQ2b* *In what manner do the explicit verbal emotional conceptualizations discriminate between dark chocolates with different low-calorie sweeteners?* *RQ2c* *To what extent is consumers' emotional eating behavior related to emotional conceptualizations of dark chocolates?* *RQ2d* *To what extent are consumers' health and taste attitudes related to acceptance of dark chocolates?* *RQ3* *To what extent do emoji as a non-verbal explicit measure contribute to the measurement of food product-elicited emotion?* *RQ3a* *In what manner do the explicit non-verbal emotional conceptualizations discriminate between different dark chocolates?* *RQ3b* *What influence has baseline mood on the non-verbal emotional conceptualizations?*
3: Examine implicit measures of subjective food product quality and food product-elicited emotion during consumption	*RQ4* *How do neurophysiological measures contribute to the understanding of consumers' food experience?* *RQ4a* *Which autonomic nervous system responses discriminate between different taste stimuli?* *RQ4b* *How does frontal alpha asymmetry discriminate between different taste stimuli?* *RQ4c* *What is the relationship between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking?*

PART II: Explicit measures of subjective food product quality and food product-elicited emotions

Research objective 2: Examine consumers' acceptance and explicit verbal and non-verbal emotional conceptualization profile of dark chocolates

In the second part of this doctoral thesis, the explicit measurement of consumers' responses to food products are examined. Both verbal (chapter 3) and non-verbal (chapter 4) measures of explicit food product-elicited emotion together with consumers' acceptance are investigated.

The most commonly used instrument to assess food product-elicited emotion is an emotional lexicon, which is a questionnaire format with a list of emotional terms. The emotional lexicon can be predefined (e.g. the EsSense Profile® by King and Meiselman (2010)) or consumer-defined (e.g. product-specific lexicons). Consumer-defined emotional lexicons have already been applied to a wide range of foods, such as blackcurrant squashes (Ng, et al., 2013), chocolate (Thomson, et al., 2010), hazelnut spreads (Spinelli, Masi, Zoboli, Prescott, & Monteleone, 2015), fruit salads (Manzocco, Rumignani, & Lagazio, 2013) and cheese (Schouteten, et al., 2015a). Although, the wide range of products, only limited studies examine the influence of different intrinsic quality cues, such as sweeteners.

Dark chocolate is used as a case in this research objective. Chocolate has a hedonic appeal due to its composition and sensory attributes (fat, sugar, texture and aroma) (Bruinsma & Taren, 1999) and is therefore often used in scientific research on consumers' emotions (Dorado, Perez-Hugalde, Picard, & Chaya, 2016; Jaeger, et al., 2013; Piqueras-Fiszman & Jaeger, 2014b; Radin, Hayssen, & Walsh, 2007; Schouteten, et al., 2015b; Spinelli, et al., 2014; Spinelli, et al., 2015; Thomson, et al., 2010). Emotions associated with chocolate consumption have been both positive and negative. Mach and Dettmer (2006) demonstrated that women experience both joy and guilt after consuming chocolate. Joy was elicited by the sensory pleasure of eating chocolate, while guilt appeared to be induced by negative thoughts associated with it (like the unwanted effect on body weight).

Sensory consumer research has increasingly been pressured by health related issues (Meiselman, 2013). One example is the interest of both food companies and consumers to reduce sugar consumption. In attempts to address consumers' demands to reduce sugar intake, sugar is increasingly substituted by sweeteners. Yet, there is a need to examine consumers' acceptance of low-calorie sweeteners (Li, Lopetcharat, & Drake, 2015). This raises the second research question and subquestions of this doctoral thesis:

Research question 2: How does a more positive, explicit verbal emotional conceptualization profile discriminate between dark chocolates?

RQ2a *How do the overall liking scores and the sensory profiles differ for dark chocolates with two low-calorie sweeteners in relation to dark chocolate with sugar?*

RQ2b *In what manner do the explicit verbal emotional conceptualizations discriminate between dark chocolates with different low-calorie sweeteners?*

RQ2c *To what extent is consumers' emotional eating behavior related to emotional conceptualizations of dark chocolates?*

RQ2d *To what extent are consumers' health and taste attitudes related to acceptance of dark chocolates?*

While various emotional lexicons have been developed, there is growing concern about the translation problem of such verbal measurements. This has led to the recent introduction of non-verbal measures, which use images to depict different emotions rather than emotional terms. Several instruments have been developed, of which the Product Emotion Measurement Instrument (PrEmo) is one of the most well-known measurements (Desmet, 2003). Recent research have applied emoji as a measure for emotional conceptualizations in a food context. Emoji are an novel version of emoticons, i.e. puntuations-based presentations of facial expersions, objects and symbols, e.g. ":-)" , that are presented in a pictoral form, e.g. through the Apple Color Emoji fontset, such as 😊) (Marengo, Giannotta, & Settanni, 2017). In comparison with PrEmo, emoji have the advantage that they are more familiar to consumers and have more potential to be used in a cross-cultural context (Jaeger, et al., 2017b). Recent studies have found that emoji can be used to discriminate emotional associations between food names and between a wide range of taste food and beverages (Jaeger, et al., 2017a; Jaeger, et al., 2017b). However, in these studies no insight was gained about the ability of emoji-based questionnaires to discriminate between products of the same category or products differing in specific sensory attributes. The researchers have stressed future studies should examine the use of emoji in a single product category product to achieve wider uptake for new product development (Jaeger, et al., 2017a). This prompts the third research question and subquestions:

Research question 3: To what extent do emoji as a non-verbal explicit measure contribute to the measurement of food product-elicited emotion?

RQ3a *In what manner do the explicit non-verbal emotional conceptualizations discriminate between different dark chocolates?*

RQ3b *What influence has baseline mood on the non-verbal emotional conceptualizations?*

PART III: Implicit measures of subjective food product quality and food product-elicited emotions

Research objective 3: Examine implicit measures of subjective food product quality and food product-elicited emotion during consumption

Part III of this doctoral thesis explores the measurement of consumers' implicit responses to food products. Implicit measures to assess responses elicited by food products could enhance the understanding of the consumers' food experience. Although explicit measures are traditionally used in consumer and sensory research, Walsh, et al. (2017a) concluded that a better understanding of implicit or unconscious emotions and motivational behavior tendencies can lead to a better assessment of consumers' food experience such as the acceptance of food products and food product-elicited emotion.

As a response to the biases and required conscious processing of explicit measures (Chai, et al., 2014; Danner, et al., 2014b; de Wijk, et al., 2012), implicit measures of acceptance and emotions have recently gained increased attention (Brouwer, et al., 2017; Samant, et al., 2017; Walsh, et al., 2017a). Implicit measures avoid the limitations of explicit measures, as they are indirect, non-self-reported and as such not under conscious control of the consumer (De Houwer & Moors, 2007; de Wijk, et al., 2012).

One of the implicit approaches is to examine neurophysiological changes in the body. Clinical neurophysiological techniques play an important role in understanding consumers' food experience (Járdánházy & Járdánházy, 2008). Unfortunately, these techniques have only been limitedly applied in sensory evaluation. Neurophysiological changes are recorded through measures of the autonomic nervous system (ANS) responses, such as cardiovascular responses or electrodermal responses. And through measures of the central nervous system (CNS), such as electroencephalogram (EEG). The CNS and the ANS mediate in an involuntary way and this is why the neurophysiological responses might bring objective information in addition to explicit responses (Haese, et al., 2014).

Compared to other sensory modalities, such as smell (Alaoui-Ismaïli, Vernet-Maury, Dittmar, Delhomme, & Chanel, 1997; Bensafi, et al., 2002a; Bensafi, et al., 2002b; Brauchli, Rüegg, Etzweiler, & Zeier, 1995; de Wijk, et al., 2012; Delplanque, et al., 2009; Martin, 1998) and appearance (images of food, Harmon-Jones and Gable (2009); Walsh, et al. (2017a); Walsh, et al. (2017b), few neurophysiological studies are conducted concerning the effect of taste on ANS activity and the brain activity (EEG). ANS responses have been found to discriminate among different basic taste solutions and these differences are associated with the hedonic valence (Rousmans, et al., 2000). A recent study used EEG to measure frontal cortex asymmetry for approach-avoidance tendency in relation to videos of food concerns (safety, hygiene and spoilage) (Walsh, et al., 2017b). They observed a higher right

FAA in response to videos with food concerns compared to control videos (which contained the same food products but without food concerns). Only one recent study included a tasting interval when measuring FAA during real-life cooking of chicken and mealworms. Although they did not find significant differences for the tasting interval, they showed approach for chicken and withdrawal for mealworms during the frying interval (Brouwer, et al., 2017).

Despite that these measures have only been limitedly applied in consumer and sensory research, they merit attention and further research. As such, this brings up the following research question and subquestions:

Research question 4: How do neurophysiological measures contribute to the understanding of consumers' food experience?

- *RQ4a* *Which autonomic nervous system responses discriminate between different taste stimuli?*
- *RQ4b* *How does frontal alpha asymmetry discriminate between different taste stimuli?*
- *RQ4c* *What is the relationship between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking?*

1.4 Research design

Data required to meet the research objectives and to investigate the research questions are collected through quantitative research procedures. Figure 1.2 provides an overview of the applied data sources and the different research designs, products and measures applied in this doctoral thesis.

The data is gathered through primary and secondary data sources. The data discussed in the doctoral thesis originates from four studies that were executed independently, including different samples and on different time points. A more detailed description of the different study samples and applied methodologies are included in the material and method sections of the appropriate chapters (chapters 2-5).

DATA SOURCE		RESEARCH DESIGN	PRODUCT	MEASURES
	PRIMARY	Consumer study n_{C3} = 219	Dark chocolate (sweeteners; sugar)	EXPLICIT - Sensory consumer questionnaire - Verbal emotional conceptualization measurement
		Consumer study n_{C4} = 146	Dark chocolate (sweeteners; sugar; label)	EXPLICIT - Sensory consumer questionnaire - Non-verbal emotional conceptualization measurement
		Consumer experiment n_{C5} = 32	Sweet and bitter solutions Personally selected drinks	IMPLICIT - Neurophysiological registration of frontal alpha asymmetry (EEG) - Neurophysiological registration of autonomic nervous system responses (ECG, EDA)
	SECONDARY	Literature review n_{C2} = 70 studies		Systematic review

Figure 1. 2 Overview of the research designs, products, measures and data sources

Secondary data sources are gathered in chapter 2 and as input information for the qualitative research. Chapter 2 collected secondary data through a systematic literature review. The final database consisted of 70 reviewed studies that were divided into the applied method. A total of 52 studies used an explicit method, 12 studies applied an implicit method and 6 studies used both explicit and implicit method. Primary data sources are collected for three quantitative research studies. Two consumer studies and a consumer experiment are conducted. In both consumer studies sensory consumer data and emotional conceptualizations (verbal measurement in chapter 3; non-verbal measurement in chapter 4) are investigated for discrimination between dark chocolates. The number of participants is 219 and 146 for chapter 3 and chapter 4 respectively. A consumer experiment is conducted in chapter 5, to assess the implicit responses to a sweet and a bitter solution and to personally selected drinks. A total of 32 participants are included in the experiment and implicit responses are collected through electroencephalogram (EEG) registration and registration of the autonomic nervous system (ANS) responses.

1.5 Intended scientific and practical contributions

This section describes how this doctoral dissertation intends to contribute to scientific research and how it is of practical relevance for food companies. The following sections discuss the intended scientific contribution (1.5.1) and the practical relevance (1.5.2) in detail.

1.5.1 Intended scientific contribution

The main scientific contribution of the doctoral dissertation is to go beyond the explicit traditional measures used in sensory research by examine implicit measures. It included measures of emotion and motivational behavior to understand underlying reaction involved in food product experience.

Part I focuses on the variety of measurements applied in consumer and sensory research to assess food product-elicited emotion. Being the first systematic review, this narrative synthesis provides an overview of the methods, measurements and instruments that are currently applied in consumer and sensory research to measure emotions in relation to food. In its overview this review includes the recent trend of implicit methods as an emerging interdisciplinary tool and as such may prompt researchers to consider measuring the consumers' food experience by building appropriate research designs including these innovative, implicit or combined approaches.

Part II takes a step beyond the traditional measurement of overall acceptance. Firstly, by adding sensory profiling, part II aims to establish a better overview on how consumers assess food product quality. Traditionally sensory profiling is performed by trained assessors in sensory analysis, however sensory profiling techniques have been developed to assess a sensory description of a food product by consumers instead of trained assessors (Valentin, Chollet, Lelievre, & Abdi, 2012). Secondly, by adding explicit emotional conceptualization profiling, part II aims to extend the existing literature on emotional conceptualizations in sensory evaluation. Moreover, part II empirically contributes to the influence of different sensory characteristics, low-calorie sweeteners, on sensory and emotional conceptualization profile. Looking to overcome the issues of verbal explicit measurements, the second chapter of part II zooms in to the use of emoji-based questionnaire instead of emotion lexicons to measure explicit non-verbal emotional conceptualizations.

Part III contributes mainly to the methodology by applying measures to identify consumers' implicit responses of acceptance and food product-elicited emotion. Implicit measures have only been limitedly applied in consumer and sensory research. Moreover, neurophysiological measures are implemented as an implicit measure in a consumer experiment. It is the first time that frontal alpha asymmetry is measured during consumption of drinks which is a major innovative methodological contribution in the field of sensory science. Furthermore, the experiment adds to the existing literature on frontal alpha asymmetry and autonomic nervous system responses in emotional and motivational research. Empirically part III contributes to the influence of tasting liked and disliked products on consumers' neurophysiological responses.

1.5.2 Practical relevance for food companies

This doctoral thesis also seeks to be of practical relevance for food companies and other stakeholders in the field of sensory and consumer science. It broadly addresses the need to evaluate both explicit and implicit level of consumers' acceptance and food product-elicited emotion to obtain a better understanding of the consumers' food experience The practical contributions are twofold: food product development and marketing.

For food product development, the knowledge gap between what is measured through explicit methods and what is measured through implicit methods is essential. As explicitly asking a consumer about overall acceptance of a food product is not always predictive for behavior, the information obtained through implicit methods can offer new insights in consumers' motivational tendencies. It proposes information about what really drives a consumer to accept a food product. For innovative food product development the consumers' perspective is essential. For the past decades, research on new product development state that food product development needs to be consumer-driven (Craig & Hart, 1992; Linnemann, Benner, Verkerk, & van Boekel, 2006; Van Trijp & Steenkamp, 2005). In order to acquire successful food product development one needs to understand the complexity of consumers' food experience (Linnemann, et al., 2006; Sijtsema, Linnemann, Gaasbeek, Dagevos, & Jongen, 2002). Hence, not only obtaining implicit liking but also the explicit emotional conceptualization profiles can enrich consumer-driven food product development.

For marketing, understanding the underlying motivational behavior and the consumer decision making processes is crucial (Breiter, et al., 2014). Traditional marketing can be enhanced through neuromarketing techniques which use neuroscience technologies in order to better understand consumers' acceptance and food choices (Ariely & Berns, 2010; Braeutigam, 2017). The measurement of neurophysiological responses upon consumption applied in this doctoral dissertation intends to contribute to this innovative field.

Additionally, sensory evaluation is crucial for nutrition policy. Understanding consumers' food experience is very important for strategies which target healthy consumption behavior and for reformulation of products.

1.6 Thesis outline

This dissertation is a compilation of papers which have been accepted, published or submitted as contributions to international peer-reviewed journals. Figure 1.3 gives an overview of the structure of this doctoral thesis.

Part I provides a general introduction to this doctoral thesis. Chapter 1 is an introductory chapter with the rational of the thesis, the rational of the conceptual framework, research objectives, research questions and research contributions and research design. Following the introductory chapter, a research chapter (chapter 2) presents insights in the measurement of food product-elicited emotion through a systematic literature review. Chapter 2 is included in this general introduction to establish a better understanding in the measurement of food product-elicited emotion.

Part II covers the explicit measures of the consumer's food experience. Two research chapters are included in this part. In both research chapters dark chocolate functions as a case. Chapter 3 looks at the sensory and emotional conceptualization profile of dark chocolates with two low-calorie sweeteners (tagatose and stevia). The emotional conceptualization profiling is done with a consumer-defined emotional lexicon, which is a verbal self-reported measure. Chapter 4 on the other hand examines the emotional conceptualization profile through a non-verbal self-reported measure.

Part III examines the consumers' food experience at an implicit level by use of implicit measures. This part consists of one research chapter (chapter 5). Chapter 5 examines implicit measures of subjective food product quality and food product-elicited emotion during consumption through neurophysiological measurements (autonomic nervous system responses and frontal alpha asymmetry). Responses of the autonomic nervous system examine consumers' food product-elicited emotions in a non-self-reported implicit way. Heart rate, heart rate variability and electrodermal responses are registered upon consumption. Frontal alpha asymmetry examines consumers' implicit acceptance of food products. Brain activity is measured through electroencephalogram (EEG). The brain signals are converted to the frontal alpha asymmetry (FAA) index.

Finally, **Part IV** provides a general discussion of the results obtained in light of the research objectives and research questions. Conclusions, implications, limitations and future research are proposed in this part.

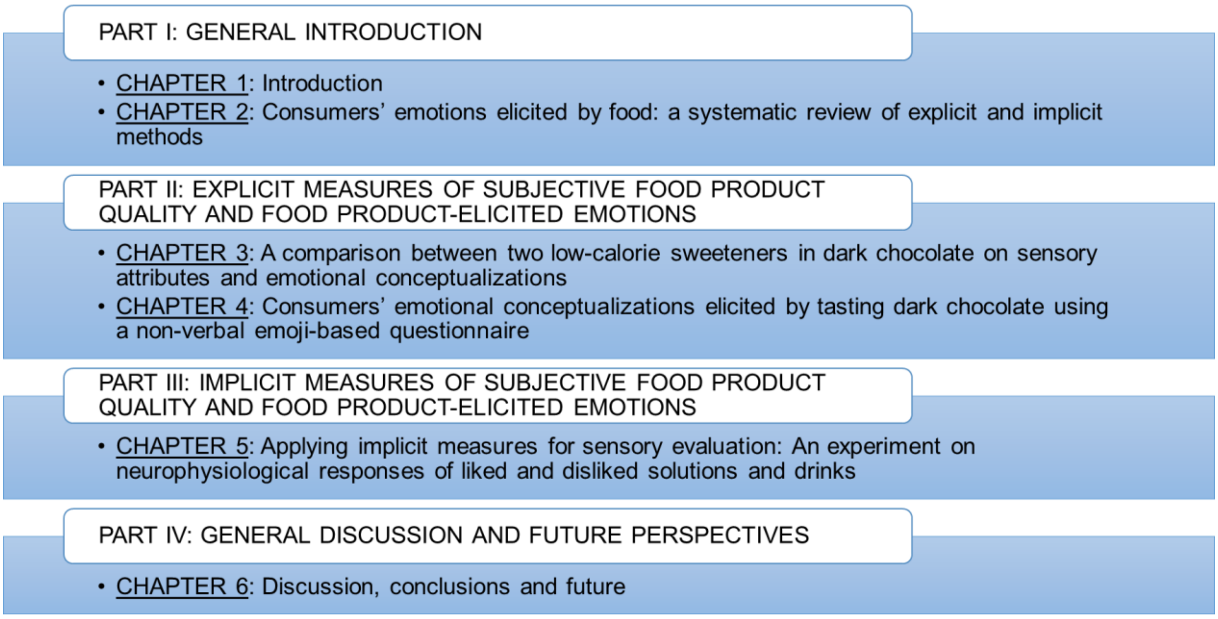

Figure 1. 3 Structure of the doctoral thesis

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Chapter 2
Consumers' emotions elicited by food: a systematic review of explicit and implicit methods

This chapter is based on:

Lagast, S., Gellynck, X., Schouteten, J.J., De Herdt, V., De Steur, H. (2017). Consumers' emotions elicited by food: a systematic review of explicit and implicit methods. *Trends in Food Science & Technology*, *69,* 172-189. IF: 5.191; R=4/130 (Q1; Food Science & Technology).

Abstract

Background

The increased interest in consumer and sensory research to focus on total consumer experience when examining the relationship between food and consumer, has led to the development of a number of instruments to capture emotional responses elicited by food, beyond sensory liking.

Scope and approach

This systematic review identified 70 studies that applied both a food preference measurement (e.g. sensory evaluation, acceptance, liking, hedonic or preference measurements) and a measurement of emotion elicited by food. The narrative synthesis provides an overview of the methods, measurements and instruments that are currently applied in consumer and sensory research to measure emotions in relation to food. Based on how emotional responses are assessed, two types of methods are distinguished: explicit and implicit methods. All studies are categorized into these two methods and structured by the applied measurement with their specific instrument.

Key findings and conclusions

The results confirm the dominance of explicit methods to investigate emotional responses in relation to food. Although implicit measurements are only limitedly applied in consumer and sensory research, the increase and evolution of (often interdisciplinary) techniques have created new, promising approaches to capture emotional responses.

Research question 1: What measurements are used in sensory and consumer research to assess consumers' food product-elicited emotion?

- *RQ1a How is food product-elicited emotion measured in sensory and consumer research?*
- *RQ1b What type of products are used for measurement of food product-elicited emotion?*
- *RQ1c How do the sample descriptives (sample size, age groups, gender) of the studies differ for each method?*

2.1 Introduction

The scientific need to better conceptualize consumers' experience with food has led to an increased interest in integrating emotions into consumer and sensory research (Gutjar, et al., 2015b; King, Meiselman, & Carr, 2013; Meiselman, 2015; Mojet, et al., 2015; Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017b). The effect of emotional responses to for example food acceptability, intention to purchase, food choice, attitudes or behavior have been examined in various ways (Walsh, et al., 2017b; Wardy, Sae-Eaw, Sriwattana, No, & Prinyawiwatkul, 2015). Whereas the influence of emotions on food choice and food intake has been examined more often (for reviews, see Canetti, Bachar, and Berry (2002); Gibson (2006); Macht (2008)), the opposite direction, i.e. food consumption influencing mood and emotion, has only recently gained attention in consumer and sensory research (Bhumiratana, Adhikari, & Chambers, 2014; Cardello, et al., 2012; Dalenberg, et al., 2014; Desmet & Schifferstein, 2008; King, Meiselman, & Carr, 2010; Ng, Chaya, & Hort, 2013a). In the last 5 years there is an increased focus on the impact of food on emotions and how this is related to food acceptance (Piqueras-Fiszman & Jaeger, 2014a, 2014b). Evidence shows that consumers' emotional associations with food products can add additional information beyond overall acceptance (Cardello, et al., 2012; Gutjar, et al., 2015b; King & Meiselman, 2010; Ng, et al., 2013a; Schouteten, et al., 2015a; Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014; Thomson, Crocker, & Marketo, 2010) and even significantly improve food choice prediction (Dalenberg, et al., 2014; Gutjar, et al., 2015a). Therefore the main reasons to include an emotional measurement in studies were product discrimination (Ng, et al., 2013a; Schouteten, et al., 2015b) and the need for a better understanding of consumers' food experiences and intake (Leitch, Duncan, O'Keefe, Rudd, & Gallagher, 2015; Piqueras-Fiszman, Kraus, & Spence, 2014).

This rising attention to emotion in consumer and sensory research has led to the introduction of many emotional instruments to capture consumers' emotions elicited by food (Dalenberg, et al., 2014). Depending on how emotional associations are assessed, these instruments can generally be divided into explicit and implicit methods. Explicit methods are either verbal or visual self-reported measurements that ask participants to report their feeling, emotions upon consumption, smelling or seeing food products. The former uses an emotional lexicon, which is a questionnaire format with a list of emotional terms or a set of emotional descriptors or a list of sentences (such as the Emosemio by Spinelli, et al. (2014)) that can be checked (e.g. Check-all-that-apply, CATA) or rated (e.g. RATA or 5-point rating scale). The CATA scale asks the consumers to check all applicable terms. The RATA scale is a variant of the CATA scale which asks the consumers to rate or indicate the intensity of the applicable term (Ares, et al., 2014). The emotional lexicon can also be predefined (e.g. the EsSense Profile® by King and Meiselman (2010)) or consumer-defined (e.g. product-specific lexicons for blackcurrant squashes (Ng, et al., 2013a), chocolate (Thomson, et al., 2010), hazelnut spreads (Spinelli, Masi, Zoboli, Prescott, & Monteleone, 2015), fruit salads (Manzocco, Rumignani, & Lagazio, 2013) and cheese (Schouteten, et al., 2015a)). Ng, et al. (2013a) were the first to compare predefined and consumer-defined emotional lexicons. Additionally, Jager, et al. (2014) assessed temporal dynamics of emotional conceptualizations during consumption by use of the technique temporal dominance of emotions (TDE). Visual self-reported methods use images to depict different emotions rather than emotional terms. Several instruments have been developed, of which the Product Emotion Measurement Instrument (PrEmo) is one of the most well-known measurements (Desmet, 2003). PrEmo was originally designed for more technical products, such as cars (Desmet, Hekkert, & Jacobs, 2000), but has been recently applied in food products, such as breakfast drinks (Dalenberg, et al., 2014), gingerbread and chocolates (den Uijl, Jager, de Graaf, Waddell, & Kremer, 2014) and odors (He, Boesveldt, de Graaf, & de Wijk, 2016). Unlike the verbal self-reported method, the visual self-reported methods are easily used in other languages as translation is not necessary (Koster & Mojet, 2015).

Although explicit measurements are quick and user-friendly they can be influenced by participant (Dalenberg, et al., 2014; Danner, Haindl, Joechl, & Duerrschmid, 2014a; de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014; de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012; Lamote, Hermans, Baeyens, & Eelen, 2004; Verhulst, Hermans, Baeyens, Spruyt, & Eelen, 2006). This is why implicit measurement of emotions has been included in studies and has recently gained increased attention. These measures are indirect and non-self-reported, cannot be controlled by the participant and register emotions while participants are consuming, smelling or looking at food, without the need of a conscious translation after the experience by the consumer (Danner, et al., 2014a; De Houwer & Moors, 2007; Mojet, et al., 2015). Most implicit measurements are registered continuously while explicit methods obtain data at certain points in time (e.g. filling in a questionnaire during or after consumption).

Interdisciplinary research (psychology, food science and medical science) has created new approaches to measure emotions in an implicit manner (Walsh, et al., 2017b) through physiological, expressive and implicit behavioral task measures (Lamote, et al., 2004). First, physiological measures are designed to tap into the underlying biological responses that accompany emotions, such as cardiovascular responses (i.e. heart rate, blood pressure), respiratory responses (i.e. respiration rate), electrodermal responses (i.e. skin conductance response, skin conductance level), brain responses (i.e. frontal alpha asymmetry) and pupillary responses (i.e. pupillary reflex) (Kreibig, 2010).

Second, expressive measures target expressive reactions, such as facial expression, that accompany emotion (Desmet, 2003; Ekman, 1993; Ekman & Friesen, 1971). Instruments that measure facial expression capture the facial muscle movements that go along with emotion (for a review, see Wieser and Brosch (2012)), either automatically (FaceReader, nViso, Affidex) or by trained coders. Another instrument that measures facial expressions is facial electromyography (EMG), which records movements of two facial muscles, the corrugator muscle (associated with positive emotion) and zygomatic muscle (associated with negative emotion)(Bailey, 2016).

Third, implicit behavioral task measures, such as the affective priming paradigm (APP), have been frequently used in psychology to register implicit attitudes and emotional responses (Klauer, Musch, Musch, & Klauer, 2003). They are generally based on measuring reaction times. Faster reactions are assumed to imply affective congruent relationships (Verhulst, et al., 2006).

Given the aforementioned differences in emotion measurement that are applied in various scientific fields, the aim of this review is to provide a comprehensive overview of methods, measurements and instruments that have been applied in consumer and sensory research to measure emotion implicitly and explicitly in relation to food in the context of food behavior (including consumption and attitudes). This overview serves as a baseline for future reference as it provides an overview of the methods for various studies. To our knowledge, this is the first systematic review on measurements of emotions elicited by food.

2.2 Method

Eligibility criteria

Peer reviewed articles found in ISI Web of Knowledge and PubMed databases that investigated (1) food preferences and (2) emotion were eligible for systematic review. Additional and more specific inclusion and exclusion criteria were used to narrow down to the relevant articles. To be included in the systematic review, a study had to be written in English, had to include a sensory modality (flavor, aroma, appearance, texture, auditory) of a food product and needed to report a measurement of emotion elicited by food. As such, studies that only conducted a measurement of preference (e.g. hedonic testing), i.e. without any measurement of emotion, were excluded (for an overview of such studies, see Booth (2014) and Pool, Sennwald, Delplanque, Brosch, and Sander (2016) for a review on liking). Inclusion and exclusion criteria are shown in Table 2.1.

Table 2. 1 Inclusion and exclusion criteria used for article selection

Inclusion
- Studies on humans - Studies with food products or food related - Investigation of both food preferences and emotion - Inclusion sensory perception (taste, smell, appearance, touch, auditory) of a food product and measurement of emotion elicited by food - Full-text articles
Exclusion
- Studies only on food preference, i.e. without any measurement of emotion - Studies in language other than English - Studies conducted with animals - Studies that included participants with eating disorders, i.e. anorexia nervosa, bulimia nervosa - Studies with focus on emotional lexicon development

Study search

The search for articles was carried out in June 2016. The syntax is developed in line with common search strategies in consumer and sensory research (Booth, 2014) and in line with studies on emotion in the field of psychology (Mauss & Robinson, 2009). The search included an a priori limit for only human studies and no restrictions were made regarding publication year. The search syntax was developed by use of the PICOS framework: Population, Intervention, Comparison, Outcome, Setting (Table 2.2). The population of interest was limited to consumers, experts, or panels (of consumers/experts). Any intervention that involved evaluation of food, taste (sweet, sour, salt, bitter or umami) or flavor and reported outcomes on sensory evaluation, acceptance, liking, hedonic or preference measurements and outcomes on emotion, mood or arousal were considered valuable. This review focused on research studies that describe preference and emotional responses to food with no limitation in setting. As this review aims to compare different methods of emotion measurements, no exclusions were made based on comparison. Key terms within the PICOS elements were combined using the Boolean operator 'OR' and between elements using the Boolean operator 'AND'. This resulted in the combination of the following keywords: (Consumer* OR Panel*OR Expert*) AND (sensory OR Accepta* OR Lik* OR Hedonic OR Pref*) AND (food OR sweet* OR sour* OR salt* OR bitter* OR umami* OR tast* OR flav*) AND (emotion* OR mood OR arousal). This search syntax was used in Web of Knowledge. For the search in PubMed this syntax was combined with the following MeSH terms: ("Food preferences"[MeSH]) AND "Emotions"[MeSH].

Table 2. 2 Application of the PICOS framework for this review

PICOS elements	Relevant search terms	Justification
Population	Consumer*, Panel*, Expert*	Limit to human population using database search limits option (Pubmed)
Intervention	Food, Sweet*, Sour*, Salt*, Bitter*, Umami*	Intervention of interest: evaluation of food products
Comparator	All study designs and comparisons	All study designs and comparisons are included
Outcome	Emotion*, Mood , Arousal Sensory, Accepta*, Lik*, Hedonic, Pref*	Targeted outcomes: emotional response both explicit and implicit; evaluation of sensory acceptance and preference
Setting	All settings	No limitation according to setting

* indicates a wildcard, representing any group of characters, including no character.

All papers retrieved were subsequently merged into one database (version X7, Thomson Reuters, NY, USA) and duplicates were removed. Two researchers conducted the search independently using the same databases and all findings were merged and discussed. The first step was based on title search for existence of important key words related to research question. Secondly, an abstract screening was conducted to review the additional relevance of the studies and finally all relevant articles were subjected to an in-depth critical full article review. This study followed the guidelines described in the PRISMA statement.

Study selection

The search strategy for this systematic review is depicted in Figure 2.1. The search resulted in an initial total of 616 records, of which 362 records were found in Web of Knowledge and 254 records were found in PubMed. A total of 9 duplicates were removed, resulting in 607 records. Based on title search for existence of important keywords related to research question, 484 were removed and 123 records were subject to abstract screening. Based on abstract screening, a total of 74 articles were included and 49 were excluded. Full-text paper was not accessible for 7 articles, which resulted in 67 articles subjected to an in-depth critical full article review and eligibility assessment.

After screening and full-text assessment 18 articles were found not eligible for inclusion based on the following criteria: no study (n=6), no emotion measurement elicited by food (n=4), no flavor or other sensory modality involved (n=4), not food related (n=2), no usage of but only focus on development of emotional lexicon (n=2). A total 49 articles were selected for analysis.

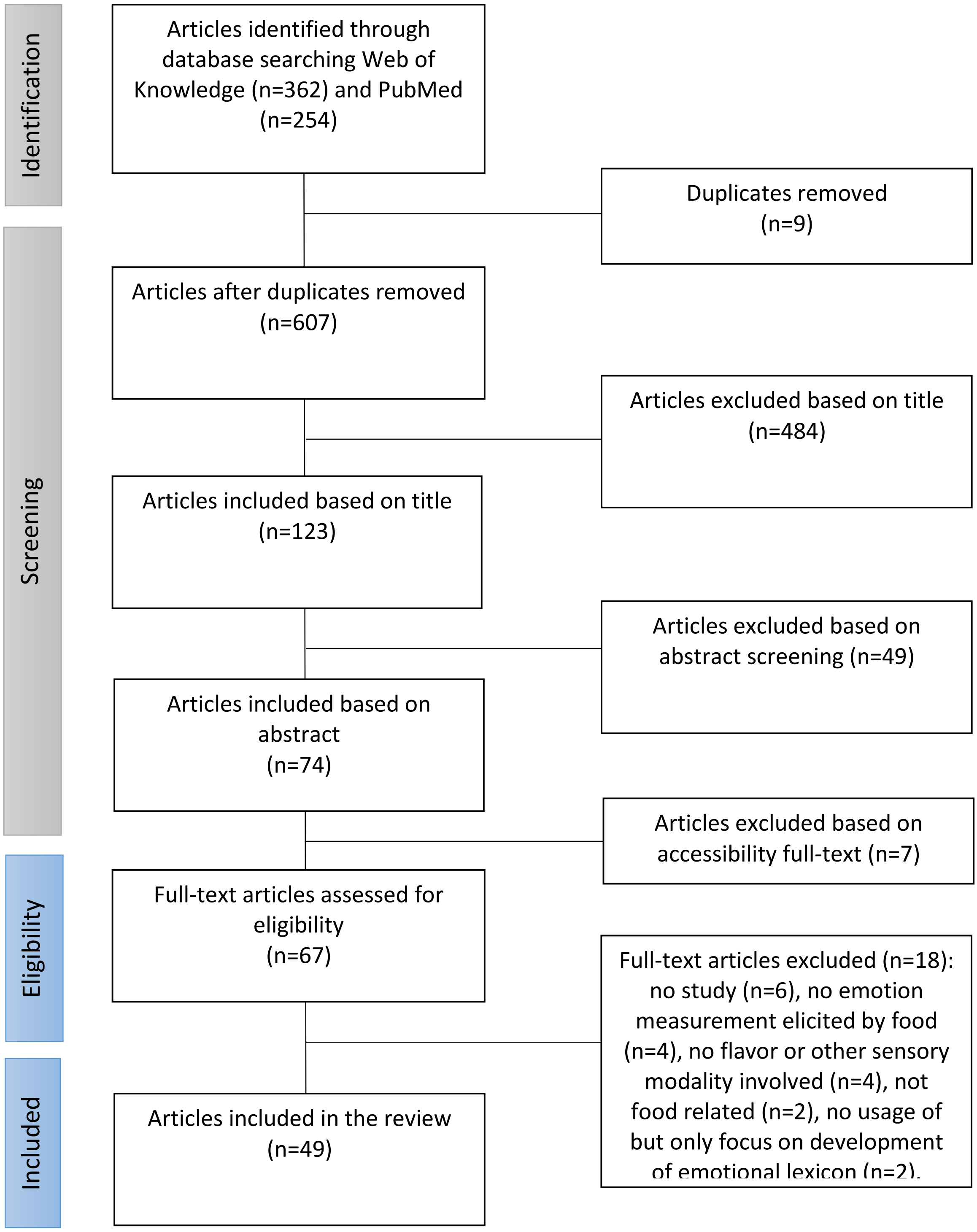


Figure 2. 1 Flow chart of search and selection of studies

Data extraction

To have a comprehensive understanding of the characteristics of the studies, data extraction sheets were developed. Information extracted from the studies included two broad categories: sensory and emotional measurement. For the emotional measurement a typology was developed to structure the variety of applied measurements (Table 2.3). The typology consisted of three categories. The first category is based on the method of emotion measurement: explicit (self-reported and direct measures of emotion) versus implicit methods (non-self-reported and indirect measures of emotion). The second category identified the type of measure, while the last category looked at the instruments used.

Next to the emotional measurement typology, the studies were categorized by sensory measurement based on the sensory modality (flavor, aroma, appearance, texture, auditory) involved in the study and were then categorized based on product category. The scale and timing of registration of the emotion measurement and the scale and timing of the sensory measurement were also extracted. Furthermore, product information (namely product category, amount of products) and general information about the study (namely country, state, setting) were extracted just like sample characteristics (namely sample size, age, gender, recruitment method, target group characteristics, type of consumer group, providing incentive for participation, ethical approval of the study).

For simplification and consistency purposes the terms ‘emotions’ or ‘emotional response’ are used throughout the review to refer to a wide range of affective concepts, associations or conceptualizations. Especially for the explicit method and measurements it needs to be made clear that it is not assumed that the emotion terms reflect experienced emotions, but rather emotional associations or emotional conceptualizations associated with the food product. However, this review adopted the terminology commonly used in this type of research and used these terms for consistency reasons.

Table 2. 3 Typology of consumers’ emotions elicited by food according to method, measure and instrument

Method	Measure	Instrument	Example
Explicit	Verbal self-reported	Emotional lexicon	EsSense profile®
	Non-verbal visual self-reported	Graphical representations	PrEmo
Implicit	Physiological	Registration of autonomic nervous system responses	Heart rate, heart rate variability
	Expressive	Registration of facial expression	FaceReader
	Implicit behavioral tasks	Registration of reaction time	Affective priming paradigm (APP) Implicit association test (IAT)

2.3 Results

The 49 articles selected for review represent a total of 72 studies, of which 38 articles have included one study, as compared to a small number of articles reporting two (6 articles), three (3 articles), six (1 article) and even seven studies (1 article). Of those 72 studies, two studies were excluded. One study was excluded because it did not include an emotion measurement, while only using a qualitative descriptive analysis (QDA) with a trained panel (Spinelli, et al., 2014). The other study was removed for review because participants were only presented with food names and not the food product itself. Thus no sensory modalities, such as flavor, aroma or appearance, were examined in that study (Jaeger, Cardello, & Schutz, 2013). The focus of the review will therefore be on those 70 studies itself, rather than the publications in which they are presented.

General characteristics

(1) <u>Study characteristics</u>

Studies were conducted in Europe (42 studies), Oceania (14 studies), North America (12 studies), Asia (3 studies) and South-America (1 study). Most studies (51 out of 70) performed their tests at a central location such as a sensory laboratory. In one study participants conducted the test at home (Home Use Test – HUT). Seven studies only report collecting responses online without requiring a specific setting for the participants. No specific setting was mentioned for 11 studies. As emotional response is likely to be context-dependent it is important to take setting under consideration. Dorado, Chaya, Tarrega, and Hort (2016a), for example, used a written scenario in a central location test to increase the relevance of the emotional response profile. Piqueras-Fiszman and Jaeger (2014a, 2014b, 2014c) instructed participants to think about an imaginary consumption setting. Some other studies have simulated a more real-life environment by carrying out the tests in a kitchen (Labbe, Ferrage, Rytz, Pace, & Martin, 2015), lounge setting (Bhumiratana, et al., 2014) or a simulated restaurant or cafeteria setting (Dalenberg, et al., 2014; Gutjar, et al., 2015a).

Sample sizes varied among the 70 studies from 12 participants to 1046 participants (MED = 100). When taking the setting into account, samples sizes varied between 12 and 303 for central location tests (CLT) (MED = 96) and between 168 and 1046 for online questionnaires (MED = 123). Smaller sample sizes were noted for implicit methods, ranging from 19 to 153 (MED = 34) and for implicit methods combined with explicit methods ranging from 12 to 161 (MED = 40).

In most studies, independently of the method type, participants were consumers of the food products that were evaluated (54 out of 70 studies). Four studies also included non-consumers or low-frequency consumers (3 studies using the explicit method and 1 study using the implicit method). Other target group characteristics were used in 40 studies, next to consumer status. Most studies, independently of the method type, focused on a young adult population (MED = 30). One study targeted children between 8 and 10 years old, while two studies investigated older populations. Younger populations were noted for implicit methods with a median of 23 years.

Although most studies targeted mixed gender groups, the proportion of women was often higher than the proportion of men participating in the studies (MED = 33 men; 48 women). Only women were targeted in 4 studies.

For recruitment some studies used participants who were members of specific panels, such as consumer or online panel. Incentives were given to participants in 36 studies. While incentives are common in sensory research and are used to motivate participants (Lawless & Heymann, 2010), they may affect participants' behavior, as shown in willingness-to-pay studies (De Steur, et al., 2014; De Steur, Wesana, Blancquaert, Der Straeten, & Gellynck, 2016). Ethical approval was explicitly mentioned in 18 studies, whereas 19 studies informed the reader about the use of an informed consent. A total of 33 studies did not give information about ethical approval in the article. An overview of the study characteristics can be found in Table 2.4.

Table 2. 4 Overview of key study characteristics categorised per method, measurement and instrument of emotion measurement

	General study characteristics		Sample characteristics							Reference
	Country (continent)	**Setting**	**Sample size *(n)***	**Consumer group**	**Panel Member**	**Age *(years)***	**Men-Women**	**Incentive**	**Ethical approval**	
Method: EXPLICIT										
Measure: Verbal self-reported										
Emotional lexicon										
- Predefined										
- EsSense Profile®	New Zealand (O)	ND	64	all	no	18-69	22-42	yes	informed consent	Jaeger, et al. (2013)
	New Zealand (O)	ND	89	all	no	19-50	35-53	yes	informed consent	Jaeger, et al. (2013)
	UK (E)	CLT	100	C	no	ND	ND	ND	ND	Ng, et al. (2013a)
	The Netherlands (E)	CLT[*~]	103	C	no	M=25.6 ±8.5	51-52	ND	yes	Gutjar, et al. (2015a)
	New Zealand (O)	ND	24	C	no	18–69	10-14	yes	informed consent	Jaeger, et al. (2013)
	New Zealand (O)	CLT[*]	192	C	no	equivalently distributed	similarly distributed	yes	informed consent	Piqueras-Fiszman and Jaeger (2014c)
	New Zealand (O)	Online	207	C	online panel	equivalently distributed	similarly distributed	yes	ND	Piqueras-Fiszman and Jaeger (2014c)
	New Zealand (O)	CLT[*]	115	C	no	18-60	48:52%	yes	informed consent	Piqueras-Fiszman and Jaeger (2014a)
	New Zealand (O)	Online	302	C,low C	online panel	20-64	C: 45:55% Low C: 41:59%	yes	informed consent	Piqueras-Fiszman and Jaeger (2014a)
	New Zealand (O)	CLT[*]	188	C	no	M=38.7 ±10.1	37:63%	yes	informed consent	Piqueras-Fiszman and Jaeger (2014a)
- Modified EsSense Profile®	USA (NA)	CLT[*]	41	all	no	18-25	8-33	ND	yes	Walsh, Duncan, Potts, and Gallagher (2015)
	Spain (E)	CLT[°]	84	all	no	18-70	40-44	ND	ND	Dorado, Perez-Hugalde, Picard, and Chaya (2016b)
	Spain (E)	CLT[′]	157	C	university panel	20-50[+]	73-84	yes	informed consent	Piqueras-Fiszman and Jaeger (2014b)
	New Zealand (O)	CLT[*]	141	C	no	20-65	47-94	yes	informed consent	Jaeger, et al. (2013)

Table 2. 4 (*Continued)*

	General study characteristics		Sample characteristics							Reference
	Country (continent)	**Setting**	**Sample size** *(n)*	**Consumer group**	**Panel Member**	**Age** *(years)*	**Men-Women**	**Incentive**	**Ethical approval**	
Method: EXPLICIT										
Measure: Verbal self-reported										
Emotional lexicon										
-Based on literature	New Zealand (O)	CLT*	96	C	recruitment panel	ND	ND	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	New Zealand (O)	CLT*	89	C	recruitment panel	ND	ND	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	Norway (E)	Online	1046	C	consumer panel	M=45 (18-60+)	ND	yes	ND	Olsen, Rossvoll, Langsrud, and Scholderer (2014)
	France (E)	CLT^	52	C	no	63-80	24-28	ND	ND	Narchi, Walrand, Boirie, and Rousset (2008)
- PANAS	USA, Japan, Korea, Germany (NA, A, E)	CLT*~	303	C, non-C	e-mail panel	18-55	ND	yes	ND	Kuesten, Chopra, Bi, and Meiselman (2014)
- Emotions in Food Experience' Scale	Australia (O)	CLT^	101	C	no	25-65	58-43	yes	yes	Lease, MacDonald, and Cox (2014)
- Consumer defined										
- Based on pre-test	UK (E)	CLT′	100	C	no	ND	ND	ND	ND	Ng, et al. (2013a)
	New Zealand (O)	CLT*	173	C	recruitment panel	ND	ND	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	New Zealand (O)	CLT*	162	C	recruitment panel	ND	ND	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	Spain (E)	CLT°	138	C	no	18-70	73-65	ND	ND	Dorado, et al. (2016b)
	UK (E)	CLT	ND	C	no	ND	ND	ND	ND	Thomson, et al. (2010)
	UK (E)	CLT*	100	C	no	19-58	45-55	ND	ND	Ng, Chaya, and Hort (2013b)
	Switzerland (E)	CLT§	60	C	no	18-60	30-30	yes	informed consent	Labbe, et al. (2015)
	Italy (E)	ND	300	C	no	18-60	ND	ND	ND	Manzocco, et al. (2013)
	France (E)	CLT^	60	C	no	M=29 ±6	0-60	ND	ND	Rousset, Deiss, Juillard, Schlich, and Droit-Volet (2005)
	UK (E)	Online	199	C	online panel	20-70	48-52%	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	UK (E)	Online	200	C	online panel	20-70	48-52%	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)
	UK (E)	Online	417	C	online panel	20-65	48-52%	yes	informed consent	Piqueras-Fiszman and Jaeger (2015)

Table 2. 4 (*Continued)*

	General study characteristics		**Sample characteristics**							**Reference**
	Country (continent)	**Setting**	**Sample size** *(n)*	**Consumer group**	**Panel Member**	**Age** *(years)*	**Men-Women**	**Incentive**	**Ethical approval**	
Method: EXPLICIT										
Measure: Verbal self-reported										
Emotional lexicon										
- EmoSensory® Wheel	Belgium (E)	CLT[′]	130	C	no	M=34 ±14	45.4-54.6%	ND	ND	Schouteten, et al. (2015b)
	Belgium (E)	CLT[*]	95	C	university panel	M=25 ±12.5	64.2-35.8%	ND	ND	Schouteten, et al. (2015b)
	Belgium (E)	CLT[′]	B: 77 I: 65	C	no	B: M=45 (18-79) I: M=44 (18-79)	B: 40-60% I: 36.4-63.6%	ND	ND	Schouteten, et al. (2015b)
	Belgium (E)	CLT[*]	129	C	university panel	M=24.9	46.6-53.4%	ND	ND	Schouteten, et al. (2015a)
- Beer-specific emotional lexicon	UK (E)	CLT[*]	200	C	no	18-51	78-122	yes	yes	Dorado, et al. (2016a)
- EmoSemio	Italy (E)	CLT	120	C	no	25-45	50-50%	yes	informed consent	Spinelli, et al. (2015)
-predefined + consumer defined										
- EsSense Profile® (39) + focus group	USA (NA)	CLT[^]	48	C	no	ND	ND	ND	ND	Bhumiratana, et al. (2014)
	USA (NA)	CLT[§]	96	C	no	18-70	32-64	ND	ND	Bhumiratana, et al. (2014)
- EsSense Profile® + EmoSemio	Italy (E)	ND	238	C	no	25-45	50-50%	yes	ND	Spinelli, et al. (2014)
- Predefined or consumer defined										
- emotional terms	Germany (E)	ND	37	C, low-freq. C	no	M=22 ±2.8	0-37	ND	ND	Macht and Dettmer (2006)
Other Verbal self-reported measures										
Free association/listing	USA (NA)	ND	41	all	no	ND	ND	ND	ND	Jaeger, et al. (2013)
Statements										
- Based on literature	USA (NA)	CLT	119	all	no	40-49 (50%)	0-119	ND	ND	Miyaki, Retiveau-Krogmann, Byrnes, and Takehana (2016)
- Profile of Mood States	USA (NA)	HUT	62	C	no	ND	ND	yes	ND	Radin, Hayssen, and Walsh (2007)
- NA	USA (NA)	Online	168	C	e-mail panel	ND	ND	ND	ND	Moskowitz, Silcher, Beckley, Minkus-McKenna, and Mascuch (2005)
- Based on literature	Korea (A)	CLT	100	C	trained + university panel	M=21 ±3	50-50	ND	informed consent	Seo, et al. (2009)
Interview										
- Modified Repertory Grid	Italy (E)	ND	75	C	no	25-45	37-38	yes	ND	Spinelli, et al. (2014)

Table 2. 4 (*Continued)*

	General study characteristics		**Sample characteristics**							**Reference**
	Country (continent)	**Setting**	**Sample size** *(n)*	**Consumer group**	**Panel Member**	**Age** *(years)*	**Men-Women**	**Incentive**	**Ethical approval**	
Method: EXPLICIT										
Measure: Non-verbal self-reported										
Affect Grid + PrEmo2	The Netherlands (E)	CLT[*]	227	C	no	M=30.8 ±9.3 (young), M=67.5 ±5.4 (normosmic), M=68.2 ±5.9 (hyposmic)	ND	ND	yes	den Uijl, Jager, Zandstra, de Graaf, and Kremer (2016)
Measure: Verbal + non-verbal self-reported										
Emotional lexicon + non-verbal self-reported measures										
- Predefined										
- Thomson and Crocker (2011) + My Pictures	USA (NA)	CLT[*~]	217, 219, 216	C	no	M=20.9 ±3.6	60-159	yes	ND	Collinsworth, et al. (2014)
- EsSense Profile® + PrEmo	The Netherlands (E)	CLT[*§]	123	C	no	18-55	33-90	yes	yes	Dalenberg, et al. (2014)
	The Netherlands (E)	CLT[*§]	123	C	no	ND	33-91	yes	yes	Gutjar, et al. (2015b)

Table 2. 4 (*Continued)*

	General study characteristics		Sample characteristics							Reference
	Country (continent)	**Setting**	**Sample size** *(n)*	**Consumer group**	**Panel Member**	**Age** *(years)*	**Men-Women**	**Incentive**	**Ethical approval**	
Method: IMPLICIT										
Measure: Expressive										
Facial expression	UK (E)	CLT´	39	C	no	17-49	17-22	ND	yes	Ahn and Picard (2014)
	Argentina (SA)	CLT´	40	all	no	M=24.2 ±5.8	12-28	ND	yes	Garcia-Burgos and Zamora (2013)
	Austria (E)	CLT*	153	C	no	M=23 ±3	71-82	ND	ND	Danner, Sidorkina, Joechl, and Duerrschmid (2014b)
Measure: Expressive + physiological										
Facial expression + ANS	The Netherlands (E)	CLT^	19	all	consumer panel	M=30 ±11.7 (women) M=36 ±12.7 (men)	9-10	yes	yes	de Wijk, et al. (2014)
	The Netherlands (E)	CLT*	31	C	partly consumer panel	M=9.25 (children) (8-10y), M=22 (young adults)	10-6 3-12	yes	yes	de Wijk, et al. (2012)
Facial expression + brain activity	Slovakia (E)	CLT*	22	C, non-C	no	ND	7-15	ND	ND	Horska, Bercik, Krasnodebski, Matysik-Pejas, and Bakayova (2016)
Facial expression + eye movements	Poland (E)	CLT*	8 QDA, 30 C test, 30 FE, 40 ET	C	no	M=23 ±ND	7-21	ND	ND	Kostyra, Wasiak-Zys, Rambuszek, and Waszkiewicz-Robak (2016)
Measure: Implicit behavioral task										
Implicit free association										
- Based on Ekman pictures	The Netherlands, Portugal (E)	CLT	56	C	no		26-30	yes	yes	Silva, et al. (2016)
Implicit priming paradigm (IPP)	Belgium (E)	CLT´	26	C	no	M=36.96 ±4.0	9-17	ND	ND	Lamote, et al. (2004)
	Belgium (E)	CLT´	29	C	no	M=19.55 ±1.8	4-25	yes	ND	Lamote, et al. (2004)
	Belgium (E)	ND	62	all	no	M=20.25 ±ND	22-40	yes	ND	Verhulst, et al. (2006)
	Belgium (E)	CLT´	36	all	no	ND	11-25	ND	ND	Hermans, Baeyens, Lamote, Spruyt, and Eelen (2005)

Table 2. 4 (*Continued)*

	General study characteristics		Sample characteristics							Reference
	Country (continent)	**Setting**	**Sample size** *(n)*	**Consumer group**	**Panel Member**	**Age** *(years)*	**Men-Women**	**Incentive**	**Ethical approval**	
Method: EXPLICIT + IMPLICIT										
Measure: Verbal self-reported + expressive										
Emotional lexicon + facial expression - Predefined										
- Modified EsSense Profile® + facial expression	USA (NA)	CLT*	30	C	consumer panel	20-60	9-22	ND	yes	Leitch, et al. (2015)
	USA (NA)	CLT*	12	all	no	18–25	more women	ND	yes	Walsh, et al. (2015)
Measure: Non-verbal self-reported + expressive										
PrEmo + facial expression	The Netherlands (E)	CLT´	26	all	no	M=22.6 ±1.5	0-26	ND	yes	He, et al. (2016)
Measure: Verbal self-reported + Implicit behavioral task										
Approach-avoidance procedure (AAP)	UK (E)	CLT*	50	C	university panel	M = 25 ±5.2	20-30%	ND	yes	Piqueras-Fiszman, et al. (2014)
Affective association measure + implicit priming paradigm (IPP)	USA (NA)	ND	161	all	no	M=23.6 ±7.2	41-59%	yes	yes	Walsh and Kiviniemi (2014)
Food emotional response questionnaire + implicit priming paradigm (IPP)	Taiwan (A)	ND	119	C	no	M=23.03 ±2.5 M=22.70 ±2.4	ND	yes	yes	Yen, et al. (2010)

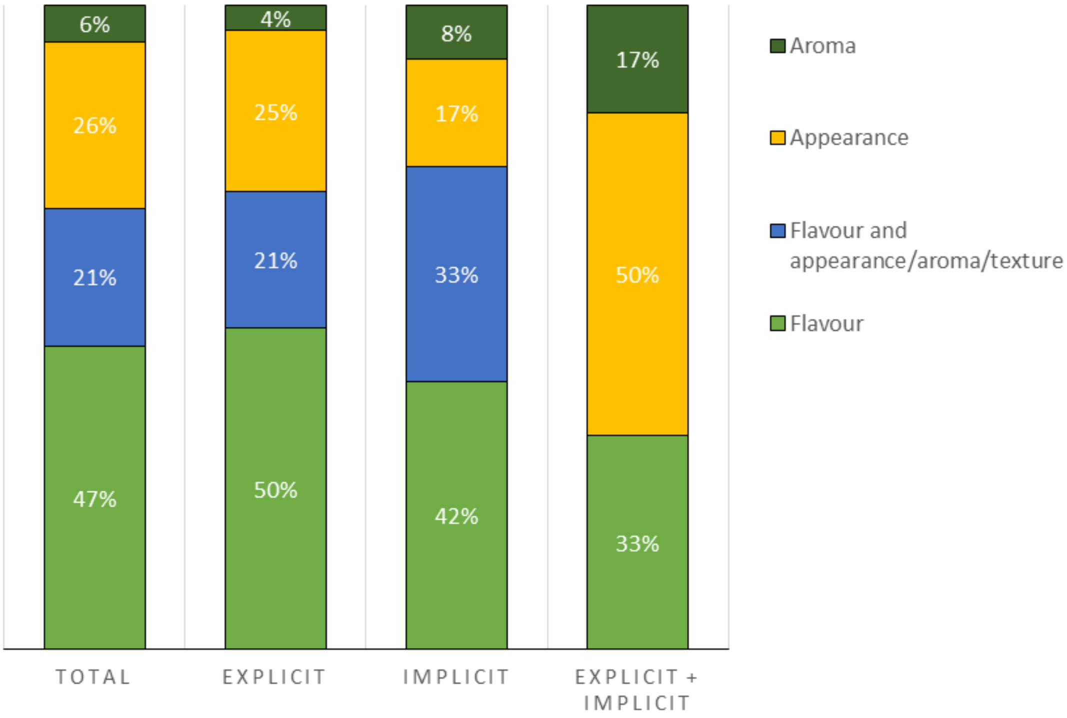
C= consumer, Continent Europe (E), Oceania (O), North-America (NA), South-America (SA), Asia (A), ND= not determined, NA= not applicable, CLT= central location test, * sensory booth or sensory facilities, ´ individual room or individual booth, ° university facilities, ˜room, ^ laboratory, § other: (simulated) eating setting, HUT = home use test, ANS = autonomic nervous response, M= mean, QDA = quantitative descriptive analysis, FE = facial expression, ET = eye tracking, B = blind condition, I = informed condition.

(2) Food products

A wide range of food products were used in the selected studies. For this review these products were categorized into a total of 6 food product categories: snacks, fruits, drinks, dairy, meat and odors. In general, the most used product categories were snacks (24 studies of which 18 featured only snacks and 6 featured snacks and another product category) and drinks (21 studies of which 17 studies featured only drinks and 4 featured drinks and another product category) (Figure 2.2a). As most studies focus on snacks and drinks, such as chocolates and fruit juices, that have a high level of acceptance, little attention is paid to food products with low levels of acceptance or with negative effects. Nevertheless, some of the reviewed studies investigated product categories with low acceptance or negative effects. Olsen, et al. (2014) investigated the explicit emotional response to rare versus well-done hamburgers using an emotional lexicon instrument. Hermans, et al. (2005) used a negative odor as unconditional stimulus in an implicit priming paradigm. Participants of the study of He, et al. (2016) were exposed to unpleasant fish odors while their facial expressions were registered. Facial expressions were also registered in response to universally disliked bitter flavors (Garcia-Burgos & Zamora, 2013) and for personally disliked foods (de Wijk, et al., 2012). As such, implicit measurements seem to be used more frequently for food products with low acceptance level. For a more detailed overview of the studies categorized by product category and sensory modality see Table 2.5.

The number of products varied widely across sensory modalities: products for tasting varied between 1 and 11, for odors between 2 and 9 (with maximum 6 samples evaluated at the same time) and for visual information between 1 and 36 images. Based on previous suggestions for emotional research by King, et al. (2013) the number of products tested for emotional measurement is important. King, et al. (2013) showed that the number of significant difference in emotions increased with the number of products in a central location test and for explicit measurement of emotions when using the EsSense Profile®.

(a)



(b)

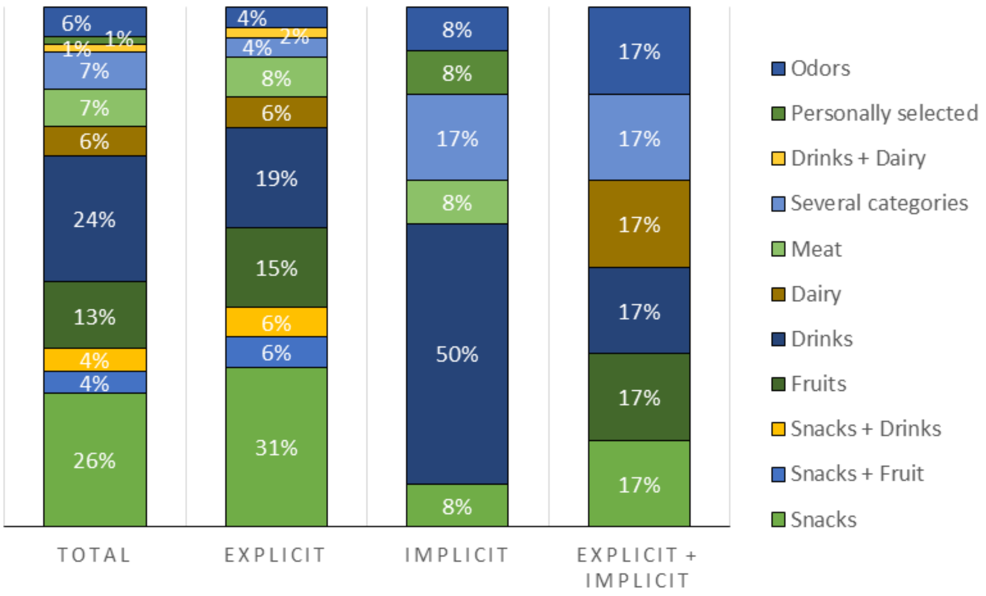


Figure 2. 2 Overview of the number of studies (in %) per method for (a) product category and (b) sensory modality

Table 2. 5 Overview of product categories categorised by applied method (explicit, implicit, explicit + implicit) and sensory modality in the study (flavor, appearance, aroma)

Method: EXPLICIT				
	Sensory modality **Flavor**	**Flavor and Appearance/ aroma/texture**	**Appearance**	**Aroma**
Emotional lexicon				
- Snacks	Dorado, Perez-Hugalde, Picard, and Chaya (2016b); Jaeger, Cardello, and Schutz (2013); Piqueras-Fiszman and Jaeger (2015); Radin, Hayssen, and Walsh (2007); Spinelli, Masi, Zoboli, Prescott, and Monteleone (2015); Thomson, Crocker, and Marketo (2010)	Piqueras-Fiszman and Jaeger (2014c); Spinelli, Masi, Dinnella, Zoboli, and Monteleone (2014)	Piqueras-Fiszman and Jaeger (2014a, 2015)	
- Snacks + Fruit	Macht and Dettmer (2006)	Jaeger, et al. (2013)	Piqueras-Fiszman and Jaeger (2014b)	
- Snack + Drinks	Gutjar, et al. (2015)	Schouteten, et al. (2015b)		
- Fruit	Jaeger, et al. (2013); Piqueras-Fiszman and Jaeger (2015)		Manzocco, Rumignani, and Lagazio (2013); Piqueras-Fiszman and Jaeger (2014a, 2014c, 2015)	
- Drinks	Bhumiratana, Adhikari, and Chambers (2014); Dorado, Chaya, Tarrega, and Hort (2016a); Dorado, et al. (2016b); (Ng, Chaya, & Hort, 2013a)	Labbe, Ferrage, Rytz, Pace, and Martin (2015); Ng, Chaya, and Hort (2013b)		
- Dairy	Walsh, Duncan, Potts, and Gallagher (2015)	Schouteten, et al. (2015a, 2015b)		
- Meat	Lease, MacDonald, and Cox (2014)	Schouteten, et al. (2015b)	Olsen, Rossvoll, Langsrud, and Scholderer (2014)	
- Several categories			Narchi, Walrand, Boirie, and Rousset (2008); Rousset, Deiss, Juillard, Schlich, and Droit-Volet (2005)	
- Aroma				Kuesten, Chopra, Bi, and Meiselman (2014)
Emotional lexicon + non-verbal self-reported measures				
- Drinks	Dalenberg, et al. (2014); Gutjar, et al. (2015)			
- Drinks + Dairy		Collinsworth, et al. (2014)		
Non-verbal self-reported measures				
- Snacks	den Uijl, Jager, Zandstra, de Graaf, and Kremer (2016)			
Other verbal self-reported measures				
- Snacks		Spinelli, et al. (2014)	Moskowitz, Silcher, Beckley, Minkus-McKenna, and Mascuch (2005)	
- Snacks + Drinks	Jaeger, et al. (2013)			
- Meat	Miyaki, Retiveau-Krogmann, Byrnes, and Takehana (2016)			
- Aroma				Seo, et al. (2009)

Table 2. 5 (*Continued)*

Method: IMPLICIT				
	Sensory modality			
	Flavor	**Flavor and Appearance/ aroma/texture**	**Appearance**	**Aroma**
Facial expression				
- Drinks	Ahn and Picard (2014); Danner, Sidorkina, Joechl, and Duerrschmid (2014)			
Facial expression + physiological measures				
- Drinks	de Wijk, He, Mensink, Verhoeven, and de Graaf (2014); Horska, Bercik, Krasnodebski, Matysik-Pejas, and Bakayova (2016)			
- Personal selected foods		de Wijk, Kooijman, Verhoeven, Holthuysen, and de Graaf (2012)		
- Meat		Kostyra, Wasiak-Zys, Rambuszek, and Waszkiewicz-Robak (2016)		
Implicit free association				
- Drinks		Silva, et al. (2016)		
Implicit priming paradigm				
- Aroma				Hermans, Baeyens, Lamote, Spruyt, and Eelen (2005)
- Several categories			Lamote, Hermans, Baeyens, and Eelen (2004)	
- Snacks		Verhulst, Hermans, Baeyens, Spruyt, and Eelen (2006)		

Method: EXPLICIT + IMPLICIT				
	Sensory modality			
	Flavor	**Flavor and Appearance/ aroma/texture**	**Appearance**	**Aroma**
Emotional lexicon + facial expression				
- Drinks	Leitch, Duncan, O'Keefe, Rudd, and Gallagher (2015)			
- Dairy	Walsh, et al. (2015)			
Non-verbal self-reported measures + facial expression				
- Aroma				He, Boesveldt, de Graaf, and de Wijk (2016)
Approach-avoidance procedure (AAP)				
- Several categories			Piqueras-Fiszman, Kraus, and Spence (2014)	
Affective association measure + implicit priming paradigm				
- Fruit			Walsh and Kiviniemi (2014)	
Food emotional response questionnaire + implicit priming paradigm				
- Snacks			Yen, et al. (2010)	

Emotional measurement

(1) <u>Method type</u>

An explicit method for measurement of emotion was the most commonly used method (52 out of 70 studies). An implicit method was applied in 12 studies and a total of 6 combined explicit and implicit methods. However, the number of studies using an implicit method (expressive and physiological measures) and the number of studies using both explicit and implicit measurement has increased over the last 3 years (Figure 2.3).

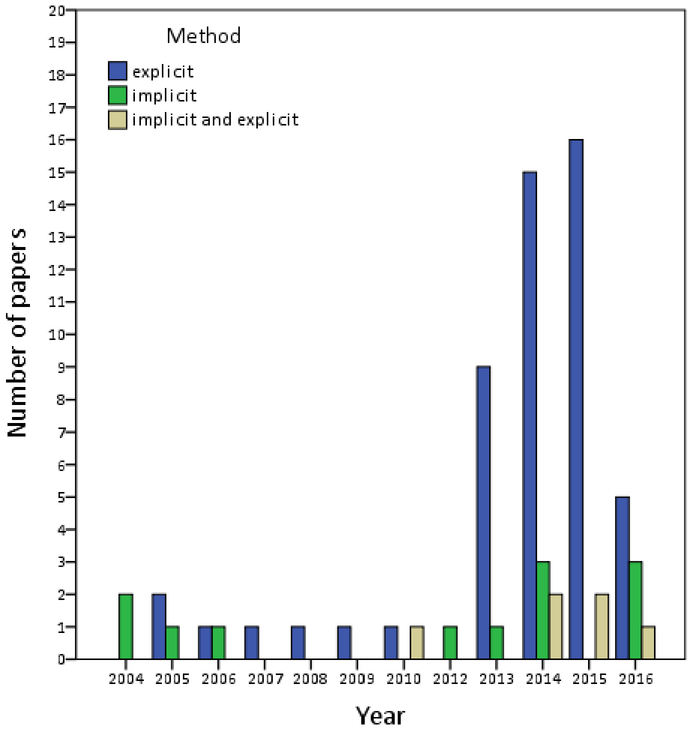


Figure 2. 3 Number of A1 publications listed in Web of Science index and PubMed per year till June 2016 (derived from this review), split up according to method (implicit/ explicit/ explicit + implicit)

In Table 2.6 all studies are categorized by type of method used to measure emotion. Following the typology (Table 2.3), the methods are further classified by type of measurement and instrument used to measure emotion. For the explicit method, three categories of measures were found: verbal self-reported measures, non-verbal self-reported measures and a combination of verbal and non-verbal self-reported measures. Also three measure categories for the implicit method were listed: expressive measures, expressive and physiological measures, and implicit behavior task measures. For the studies that combined the explicit and implicit method also three categories were recognized: verbal self-reported and expressive measures, non-verbal self-reported measures and expressive measures, and verbal self-reported measures and implicit behavioral task measures.

Table 2. 6 Overview of studies that applied an emotional and sensory measurement. Instruments of emotion measurement categorised per method and measure

	Emotional measurement		**Sensory measurement**			**Reference**
	Scale	**Timing of registration**	**Sensory modality**	**Liking scale**	**Timing of sensory measurement**	
Method: EXPLICIT						
Measure: Verbal self-reported						
Emotional lexicon						
- Predefined						
- EsSense Profile®	rating 5-point scale	after flavor	flavor	9-point scale	before emotion	Jaeger, et al. (2013)
					before emotion	Jaeger, et al. (2013)
					before emotion	Ng, et al. (2013a)
					after emotion	Gutjar, et al. (2015a)
			flavor + texture		after emotion	Jaeger, et al. (2013)
		after flavor after appearance	flavor + appearance	no liking*	after emotion	Piqueras-Fiszman and Jaeger (2014c)
		after appearance	appearance	no liking*	after emotion	Piqueras-Fiszman and Jaeger (2014c)
					after emotion	Piqueras-Fiszman and Jaeger (2014a)
					after emotion	Piqueras-Fiszman and Jaeger (2014a)
					after emotion	Piqueras-Fiszman and Jaeger (2014a)
- Modified EsSense Profile®	CATA	after flavor	flavor	9-point scale	before emotion	Walsh, et al. (2015)
	rating 5-point scale				before emotion	Dorado, et al. (2016b)
	rating 5-piont scale	after appearance	appearance	no liking*	after emotion	Piqueras-Fiszman and Jaeger (2014b)
	best-worst scaling	after flavor	flavor	9-point scale	before emotion	Jaeger, et al. (2013)
- Based on literature	CATA	after flavor	flavor	no liking*	after emotion	Piqueras-Fiszman and Jaeger (2015)
		after flavor	flavor	no liking*	after emotion	Piqueras-Fiszman and Jaeger (2015)
	CATA	after appearance	appearance	no liking**	after emotion (separate session)	Olsen, et al. (2014)
	rating 5-point scale	after appearance	appearance	5-point scale	simultaneously	Narchi, et al. (2008)
- PANAS	rating	after aroma	aroma	rating	before emotion	Kuesten, et al. (2014)
- Emotions in Food Experience' Scale	rating 5-point scale	after flavor	flavor	9-point scale	before emotion	Lease, et al. (2014)

Table 2. 6 (*Continued)*

	Emotional measurement		Sensory measurement			Reference
	Scale	**Timing of registration**	**Sensory modality**	**Liking scale**	**Timing of sensory measurement**	
Method: EXPLICIT						
Measure: Verbal self-reported						
Emotional lexicon						
- Consumer defined						
- Based on pretest	CATA	after flavor	flavor	9-point scale	before emotion	Ng, et al. (2013a)
				no liking*	after emotion	Piqueras-Fiszman and Jaeger (2015)
					after emotion	Piqueras-Fiszman and Jaeger (2015)
	line scale	after flavor		15 cm line scale	before emotion	Dorado, et al. (2016b)
	best-worst scaling	ND		ND	ND	Thomson, et al. (2010)
	CATA	after flavor after appearance	flavor + appearance	9-point scale	before emotion	Ng, et al. (2013b)
	line scale	before and after	flavor + appearance + aroma + hearing + texture	100-mm VAS	before emotion	Labbe, et al. (2015)
	CATA	after appearance	appearance	9-point scale	before emotion	Manzocco, et al. (2013)
	rating			5-point scale	ND	Rousset, et al. (2005)
	''Bulls-eye'' approach	after appearance		no liking*	before emotion	Piqueras-Fiszman and Jaeger (2015)
					before emotion	Piqueras-Fiszman and Jaeger (2015)
					before emotion	Piqueras-Fiszman and Jaeger (2015)
- EmoSensory® Wheel	RATA	after	flavor + appearance + aroma + texture	9-point scale	simultaneously	Schouteten, et al. (2015b)
				9-point scale	simultaneously	Schouteten, et al. (2015b)
				9-point scale	simultaneously	Schouteten, et al. (2015b)
				7-point scale	simultaneously	Schouteten, et al. (2015a)
- Beer-specific emotional lexicon	rating (line scale)	after flavor	flavor	line scale	after emotion	Dorado, et al. (2016a)
- EmoSemio	rating 5-point scale	after flavor	flavor	9-point scale	before emotion	Spinelli, et al. (2015)

Table 2. 6 (*Continued)*

	Emotional measurement		Sensory measurement			Reference
	Scale	**Timing of registration**	**Sensory modality**	**Liking scale**	**Timing of sensory measurement**	
Method: EXPLICIT						
Measure: Verbal self-reported						
Emotional lexicon						
-Predefined + consumer defined						
- EsSense Profile® (39) + focus group	CATA	after flavor	flavor	no liking	NA	Bhumiratana, et al. (2014)
- EsSense Profile® (39) + focus group	rating 5-point scale	before and after	flavor	9-point scale	before emotion	Bhumiratana, et al. (2014)
- EsSense Profile® (39) + EmoSemio	rating 5-point scale	after	flavor + aroma	9-point scale	before emotion	Spinelli, et al. (2014)
- Predefined or consumer defined						
- Emotional terms	rating	fixed time: 5, 30, 60 and 90 min	flavor	7-point scale	after emotion	Macht and Dettmer (2006)
Measure: Other verbal self-reported						
Free association/listing	free listing	after flavor	flavor	no liking	ND	Jaeger, et al. (2013)
Statements						
- Based on literature	rating 5-point scale	after flavor	flavor	9-point scale	before emotion	Miyaki, et al. (2016)
- Profile of Mood States	rating 5-point scale	after flavor	flavor	no liking	NA	Radin, et al. (2007)
- NA	conjoint	no tasting	appearance (+aroma + flavor + texture)	FACT Scale	NA	Moskowitz, et al. (2005)
- Based on literature	semantic differential scales	after odor	aroma	9-point scale	after emotion	Seo, et al. (2009)
Interview						
- Modified Repertory Grid Method (RGM)	interview	after flavor after appearance	flavor + appearance	no liking***	before emotion	Spinelli, et al. (2014)
Measure: Non-verbal self-reported						
- Affect Grid + PrEmo2	rating	after flavor	flavor	9-point scale	before emotion	den Uijl, et al. (2016)
Measure: Verbal + non-verbal self-reported						
Emotional lexicon + non-verbal self-reported measures						
- Predefined						
- Thomson and Crocker (2011) + My Pictures	CATA	before and after	flavor + texture	9-point scale	begin + during + end	Collinsworth, et al. (2014)
- EsSense Profile® + PrEmo	rating 5-point scale	after flavor	flavor	100-mm VAS	after emotion	Dalenberg, et al. (2014)
	rating 5-point scale	after flavor	flavor	100-mm VAS	after emotion	Gutjar, et al. (2015b)

Table 2. 6 (*Continued)*

	Emotional measurement		Sensory measurement			Reference
	Scale	**Timing of registration**	**Sensory modality**	**Liking scale**	**Timing of sensory measurement**	
Method: IMPLICIT						
Measure: Expressive						
Facial expression	human coders	continuous	flavor	9-point scale	during	Ahn and Picard (2014)
	FaceReader	continuous	flavor	9-point scale	during	Garcia-Burgos and Zamora (2013)
	FaceReader	continuous	flavor	9-hedonic scale	after emotion	Danner, et al. (2014b)
Measure: Expressive + physiological						
Facial expression + ANS	FaceReader + SCR, FT, HR	continuous	flavor	100-mm VAS	after implicit measurement	de Wijk, et al. (2014)
	FaceReader + SCR, FT, HR	continuous	flavor + appearance + aroma	7-point scale	before (preselected)	de Wijk, et al. (2012)
Facial expression + brain activity	FaceReader + EEG	continuous	flavor	9-point scale	during emotion registration	Horska, et al. (2016)
Facial expression + eye movements	FaceReader + Eye Tracking	continuous	flavor + appearance + texture	9-point scale	during emotion registration	Kostyra, et al. (2016)
Measure: Implicit behavioral task						
Implicit free association						
- Based on Ekman pictures	free association	after flavor after appearance	flavor + appearance	no liking	NA	Silva, et al. (2016)
Implicit priming paradigm (IPP)	reaction time	during appearance	appearance	NA	NA	Lamote, et al. (2004)
	reaction time	during appearance	appearance	NA	NA	Lamote, et al. (2004)
	forced choice	NA	flavor + appearance	21-point rating scale	NA	Verhulst, et al. (2006)
	reaction time	NA	aroma	NA	NA	Hermans, et al. (2005)

Table 2. 6 *Continued*

	Emotional measurement		Sensory measurement			Reference
	Scale	**Timing of registration**	**Sensory modality**	**Liking scale**	**Timing of sensory measurement**	
Method: EXPLICIT + IMPLICIT						
Measure: Verbal self-reported + expressive						
Emotional lexicon + facial expression						
- Predefined						
- Modified EsSense Profile® + facial expression	CATA + FaceReader	after flavor + continuous	flavor	9-point scale	before emotion	Leitch, et al. (2015)
	CATA + FaceReader	after flavor + continuous	flavor	9-point scale	before emotion	Walsh, et al. (2015)
Measure: Non-verbal self-reported + expressive						
PrEmo + facial expression	rating 5-point scale + FaceReader	after aroma + continuous	aroma	100-mm VAS	before emotion	He, et al. (2016)
Measure: Verbal self-reported + Implicit behavioral task						
Approach-avoidance procedure (AAP)	100-mm VAS + reaction time	after AAP/during appearance + during appearance	appearance	100-mm VAS	after AAP	Piqueras-Fiszman, et al. (2014)
Affective association measure (~lexicon) + implicit priming paradigm (IPP)	8-point scale + reaction time	before and after priming + during appearance	appearance	no liking***	after IPP	Walsh and Kiviniemi (2014)
Food emotional response questionnaire + implicit priming paradigm (IPP)	4-likert scale + reaction time	before IPP + during appearance	appearance	NA	NA	Yen, et al. (2010)

* = appropriateness to eat, ** = likelihood to eat, *** = forced choice, NA = not applicable, ND = no determined, CATA = check-all-that-apply, RATA = rate-all-that-apply, VAS = visual analog scale, SCR = skin conductance response, FT = finger temperature, HR = heart rate, EEG = electroencephalogram, ANS = autonomic nervous response

(2) Explicit instruments (52 studies)

Explicit measurement of emotion was most frequently applied through an emotional lexicon, a questionnaire format with a list of emotional terms (or sentences) that can be checked (e.g. Check-all-that-apply, CATA) or rated (rate-all-that-apply (RATA) or 5-point rating scale) (46 out of 52). The studies applying the emotional lexicon were divided into three categories: predefined (24 studies), consumer-defined (19 studies) and a combination of predefined and consumer-defined (3 studies).

The EsSense Profile® questionnaire is considered as 'the' illustrative example of explicit measurement method. In the reviewed studies the EsSense Profile® by King and Meiselman (2010) (either modified or not) was mostly applied in explicit emotion research (19 studies). Other predefined emotional lexicons used in the reviewed studies were PANAS (1 study), Emotions in food experience' scale (1 study), Profile of Mood states (1 study) and lexicons based on existing literature (4 studies).

A total of 19 studies applied consumer-defined lexicons developed mostly via pretest in which consumers need to define the emotional terms that will be used in the evaluation of the product.

Three studies applied an emotional lexicon with non-verbal representations. The EsSense Profile® was combined with PrEmo in two studies and another study combined the lexicon developed by Thomson and Crocker (2011) with Image Measurement of Emotion and Texture (IMET), which is an instrument where participants are asked to create their own 'My pictures board' with self-selected images representing 12 different emotions (Collinsworth, et al., 2014).

The number of emotional terms used in a lexicon varied from 5 (fear, disgust, pleasure, interest and surprise; Olsen, et al. (2014)) to 47 for the predefined lexicons, whereas the number of terms for the consumer-defined lexicons varied from 10 to 50. An emotional lexicon also typically holds terms that can be classified as positive, negative or neutral. Most reviewed studies tended to use more positive (average of 17.17 terms) than negative terms (average of 8.25 terms) in the lexicon. The general idea that food elicits positive emotions (hedonic asymmetry) might explain that dominance of positive emotional terms in the emotional lexicons (Table 2.7).

Table 2. 7 Comparison of emotional lexicon instrument based on number of emotional terms used categorized in total number, number of positive, negative and neutral terms

Emotional lexicon	Number of emotional terms total	positive	negative	neutral	Reference
➢ Predefined					
• EsSense Profile®	39	25	3	11	Gutjar, et al. (2015a); Jaeger, et al. (2013); Ng, et al. (2013a); Piqueras-Fiszman and Jaeger (2014a, 2014c)
• Modified EsSense Profile®	ND	ND	ND	ND	Walsh, et al. (2015)
	38	24	3	11	Dorado, et al. (2016b)
	36	24	2	10	Piqueras-Fiszman and Jaeger (2014b)
	16-21	ND	ND	ND	Jaeger, et al. (2013)
• Based on literature	47	balanced	balanced	ND	Piqueras-Fiszman and Jaeger (2015)
	47	balanced	balanced	ND	Piqueras-Fiszman and Jaeger (2015)
	5	2	2	1	Olsen, et al. (2014)
	19	8	11	0	Narchi, et al. (2008)
• PANAS	20	10	10	0	Kuesten, et al. (2014)
• Emotions in Food Experience' Scale	18	11	7	0	Lease, et al. (2014)
• Profile of Mood States	30	ND	ND	ND	Radin, et al. (2007)
➢ Consumer defined					
• Based on pretest	36	16	19	1	Ng, et al. (2013a)
	20	10	10	0	Piqueras-Fiszman and Jaeger (2015)
	18	9	9	0	Piqueras-Fiszman and Jaeger (2015)
	12 cat	ND	ND	ND	Dorado, et al. (2016b)
	24	ND	ND	ND	Thomson, et al. (2010)
	34 (blind); 38 (pack); 50 (informed)	15 (blind); 24 (pack); 26 (informed)	18 (blind); 14 (pack); 23 (informed)	1 (blind); 0 (pack); 1 (informed)	Ng, et al. (2013b)
	39	ND	ND	ND	Labbe, et al. (2015)
	29	14	11	4	Manzocco, et al. (2013)
	26	ND	ND	ND	Rousset, et al. (2005)
	26	balanced	balanced	ND	Piqueras-Fiszman and Jaeger (2015)
	27	balanced	balanced	ND	Piqueras-Fiszman and Jaeger (2015)
	10	5	5	0	Piqueras-Fiszman and Jaeger (2015)
• EmoSensory® Wheel	17	ND	ND	ND	Schouteten, et al. (2015b)
	14	7	7	0	Schouteten, et al. (2015b)
	15	7	7	1	Schouteten, et al. (2015b)
	13	6	6	1	Schouteten, et al. (2015a)
• Beer-specific emotional lexicon	10 cat	ND	ND	ND	Dorado, et al. (2016a)
• EmoSemio	23	ND	ND	ND	Spinelli, et al. (2015)
➢ Predefined + consumer defined					
• EsSense Profile® (39)	118	ND	ND	ND	Bhumiratana, et al. (2014)
+ focus group	86	64	11	11	Bhumiratana, et al. (2014)
• EsSense Profile®	39	25	3	11	Spinelli, et al. (2014)
EmoSemio	23	ND	ND	ND	
➢ Predefined or consumer defined					
• Emotional terms	11	ND	ND	ND	Macht and Dettmer (2006)
Emotional lexicon + non-verbal representation					
➢ Predefined					
• Thomson and Crocker (2011) + My Pictures	12	5	5	2	Collinsworth, et al. (2014)
• EsSense Profile® +	39	25	3	11	Dalenberg, et al. (2014)
PrEmo	39	25	3	11	Gutjar, et al. (2015b)
Emotional lexicon + facial expression					
➢ Predefined					
• Modified EsSense Profile®	43	26	6	12	Leitch, et al. (2015)
	ND	ND	ND	ND	Walsh, et al. (2015)

Cat = categories, ND = not determined.

Other explicit instruments for emotion measurement applied in the reviewed studies were free listing (2 studies), statements (2 studies), semantic differential scales (1 study), interview (1 study) and non-verbal representations (1 study).

In most studies the timing of the emotional measurement took place after sensory perception of the product (46 studies). Macht and Dettmer (2006) conducted emotion measurements at fixed intervals (5, 30, 60 and 90 min) after tasting. Only three studies did an emotional assessment before as well as after tasting.

(3) Implicit instruments (12 studies)

Of the 70 studies reviewed, only 12 studies used implicit methods, either expressive and physiological measures or implicit behavioral task measures. The registration of facial expressions was most popular (7 out of 12). Facial expressions were mostly automatically registered via FaceReader software, which automatically encodes the facial expressions into the six basic emotions defined by Ekman (1993) (6 out of 7). Three studies only used the facial expression instrument, whereas other studies combined it with physiological measures, either registration of autonomic nervous responses (ANS) (two studies), brain responses (1 study) or eye movements (1 study). In these studies emotional responses were registered continuously. Besides expressive and physiological measures, implicit association and priming approaches were also applied (5 out of 12). An implicit free association method was used in one study which applied the five basic emotion pictures of Ekman (1993). The implicit priming paradigm was applied in 4 studies where reaction time was measured.

(4) Studies combining explicit and implicit instruments (6 studies)

A total of 6 studies combined both explicit and implicit methods for measuring emotion elicited by food. The explicit method using an emotional lexicon (modified EsSense Profile®) was combined with the implicit method of facial expression (2 studies), while the latter was also combined with the non-verbal, visual self-reported measure, PrEmo (1 study). Another implicit instrument was applied by Piqueras-Fiszman, et al. (2014) who used the approach-avoidance procedure (AAP) which measures people's approach and avoidance tendencies towards the presented foods in an implicit way by using a joystick based AAP. Participants were instructed to push or pull the joystick when a food stimulus was presented while reaction time was registered.

In 2 studies, the implicit priming paradigm was combined with a verbal self-reported explicit instrument, namely the affective association measure or the food emotional response questionnaire.

While in the former participants were prompted with the sentence "When I think about eating fruit and vegetables, I feel …" followed by 7 positive emotional term and 7 negative emotional terms, the latter targeted 4 statements related to perceived emotions.

As measures of facial expression are registered in a continuous way, there was no specific order in performing the explicit and implicit measure. For the studies that used an implicit behavioral measure as implicit measurement, the reaction time of the participant was measured from the onset of the stimuli (appearance) until the response of the participant. Therefore the implicit emotional measurement was registered during the appearance of the product and the explicit emotional measurement was registered before and/or after the implicit behavioral task during the appearance of the same products used in the implicit behavioral task. Walsh and Kiviniemi (2014) measured the explicit affective associations at baseline (before) and post-priming, whereas Yen, et al. (2010) assessed the food emotional response only before priming. Piqueras-Fiszman, et al. (2014) asked the participants to rate each food image that was used as a stimulus during the AAP after the implicit measurement.

Sensory measurement

In most studies (48 out of 70) participants were asked to taste a food product. Only 15 studies combined flavor with another sensory modality, 33 studies focused on flavor alone. A total of 22 studies did not include flavor and examined another sensory modality. Here, mostly visual information or appearance of the food products, such as food pictures or images of food, were given (18 out of 22) (Figure 2.2b). Four studies provided an aroma as a stimulus to the participants.

In most studies (48 out of 70) participants were asked to taste a food product. Some studies focused only on flavor (33 studies) whereas others combined flavor with other sensory modalities (aroma, appearance, texture) (15 studies). Notable is the dominance of only flavor, as flavor has been described as one of the most important factors when making product choices (Köster, 2003; Leitch, et al., 2015; Schifferstein, Fenko, Desmet, Labbe, & Martin, 2013) (Table 2.6).

In Figure 2.2b, the number of studies is shown for each method for each sensory modality. Investigating only flavor of food products was dominant in both explicit (50% of the 52 studies) and implicit methods (42% of the 12 studies). A focus on flavor and appearance, aroma and/or texture accounted for 21% of the explicit and 33% of the implicit methods. For the combined method (explicit and implicit) mainly visual stimuli of food (appearance) were subject of research (50% of the 6 studies).

2.4 Discussion

This is the first study that systematically reviews (both explicit and implicit) methods, measurements and instruments that have been applied in consumer and sensory research to measure emotion elicited by food in the context of food behavior. It provides a comprehensive overview and builds on the increased interest in the relationship between food and consumer, which goes beyond sensory liking, by indicating trends and challenges of capturing emotional responses elicited by food. A total of 70 studies were reviewed.

Although there are several ways to measure emotion elicited by food, explicit methods are the most prominent (52 studies). Explicit methods thus remain a popular approach among practitioners in consumer and sensory research, because they are quick in use and the data is easy to process (Dorado, et al., 2016b). Besides the fast and easy approach, explicit methods are user-friendly as they do not require much involvement of the participant. Nevertheless, studies mention major limitations and problems of explicit methods. First, explicit methods run the risk of being influenced by the participant, which may affect the validity of the emotional assessment (Danner, et al., 2014b; de Wijk, et al., 2012). Second, social desirability and self-representation biases can similarly influence the explicit self-reported measures of emotion (Chai, et al., 2014; Schwarz & Oyserman, 2001). A third limitation is that explicit methods are to some degree retrospective as emotions are elicited after the experience (Danner, et al., 2014a). Fourth, some participants can lack the introspective capacity to correctly identify, recognize and then verbalize the perceived emotion (Köster, 2003; Nisbett & Wilson, 1977).

Within these explicit methods, most studies applied an emotional lexicon as testing instrument (46 studies). A well-known difficulty of the emotional lexicon is the translation problem. When translating emotional terms meaning is lost, which makes it hard to apply in a multicultural setting. Furthermore, cultural differences in emotional perception and experience can also be problematic in these measurements (van Zyl & Meiselman, 2016). Moreover, some consumers might consider using certain words to describe how they feel rather strange as reported by Jaeger, et al. (2013) and might select emotional terms even if they are not really experiencing them before, during or after consumption (Thomson & Crocker, 2015). Because of the problems of the emotional lexicons, non-verbal self-reported measurements are on a rise. Non-verbal self-reported instruments, such as Product Emotion Measurement Instrument (PrEmo) can circumvent these problems, as translation is not necessary. (Koster & Mojet, 2015). However, consumers are not very familiar with these pictograms and possibly uncertain about the meaning of the graphical representations. A possible solution lies in the use of emoji, which have been recently suggested as an alternative way to capture the explicit non-verbal emotions elicited by food products (Jaeger, et al., 2017a). Despite this innovative technique, the meaning of emoji cannot always be interpreted unambiguously (Jaeger and Ares, 2017; Miller et al., 2016).

Explicit methods might apply either a predefined or consumer-defined list of terms or visual images. Whereas a predefined list has the advantage that it is easier and more cost-efficient to apply, one should bear in mind that it contains many items in order to ensure that no important emotions are missed (Jaeger, et al., 2013; Spinelli, et al., 2015). In contrast, a consumer-defined list contains a step to select the most appropriate terms or visual images for the product category under study enabling a shorter list. One should consider that including too many items might hamper the emotional profiling task and consequently lower the quality of the collected data (Jaeger, et al., 2013; Ng, et al., 2013a). Therefore, a consumer-defined list has been recommended when working with emotion terms based upon research comparing both methodologies (Ng, et al., 2013a). Although many studies have worked with a consumer-defined list (Dorado, et al., 2016a; Ng, et al., 2013a; Piqueras-Fiszman & Jaeger, 2014a; Schouteten, et al., 2015b), it is noteworthy to mention that the selection is often not clearly described in the papers. The usage frequency and ability to discriminate between product samples are often mentioned as criteria but most papers do not mention the details of the application such as the exact percentage for the usage frequency. The criteria listed by Jiang, King, and Prinyawiwatkul (2014) could be recommended when selecting the final terms or visual images for a consumer-defined emotion lexicon.

It is important to note that the number of emotional terms used within the emotional lexicons applied in the studies varied greatly, ranging from only 5 to 50. There is a tendency to use long lists of emotional terms as most lexicons consisted of more than 30 terms. Although these lexicons are good to detect differences among products, there is a growing concern about the length of the lexicons. As a result the EsSense Profile® has recently been redesigned into a shorter version limited to 25 terms (Nestrud, Meiselman, King, Lesher, & Cardello, 2016). This reflects two opposing needs in emotional research: obtaining a full characterization which requires sufficient terms contradicts with the need to keep the task as short as possible to make it easier for the consumer. Also, a longer list might lead to the inclusion of redundant terms (e.g. synonyms or closely related terms) which might confuse participants of the emotional profiling task (Jaeger, et al., 2013). Overall, it is recommended to keep the burden for the participants as low as possible and as such to limit the number of items in explicit methods. More research is recommended with a broad variety of product categories to examine the impact of the number of terms on the emotional profiling of food products. Moreover, one should also consider the length of the overall task as a longer list of items might be compensated by limiting the number of products under study. Specifically for the widely applied EsSense Profile, it has been recommended to only use two products (King, et al., 2013), but this hampers the efficiency of data collection when a broad range of products needs to be examined and also limits the validity as consumers often choose between more than two products in real life.

Three types of response formats are commonly used for the explicit measurements: (i) rating, (ii) CATA and (iii) RATA. CATA focuses on the use of applicability of the selected terms and is the recommended response format when working with emotions of higher intensity and for the selection of items when establishing a consumer-defined list (Jiang, et al., 2014). Given that CATA does not require rating, it has the benefit that it shortens response time and requires a lower cognitive involvement which limits the effect on the emotional measurements (Ares, et al., 2014; Vidal, Ares, Hedderley, Meyners, & Jaeger, 2016). RATA and rating scales provide a broader picture as these response formats are more sensitive than CATA. Due to the rating RATA and rating scales can be treated with many statistical methods whereas the statistical analysis of CATA is rather limited as it involves binary data. However, as the cognitive involvement of RATA and rating scales is higher, it could discourage the use of satisfying response strategies by consumers (Schouteten, et al., 2017b). RATA scales have the advantage that it requires less time compared to the rating scale. Yet, by asking participants to rate all emotions with for instance the option 'not at all applicable' as foreseen in the EsSense Profile™ (King & Meiselman, 2010) might make the task easier for consumers. Given the advantages and limitations of these response formats, the individual researcher should select the most appropriate response format depending on the goal of the research.

Implicit methods to measure emotion avoid the limitations of the explicit method. As they are indirect and non-self-reported, they are not under the conscious control of the consumer (De Houwer & Moors, 2007; de Wijk, et al., 2012). Yet, these methods are only scantly explored in consumer and sensory research. This review found 18 studies, of which 12 studies only applied implicit methods and 6 studies combined explicit and implicit methods. The use of an implicit method was mostly the result of interdisciplinary research as techniques from psychology and medical science are applied. Examples are the priming paradigm and IAT which are frequently used in psychology. Similarly, the measurements of autonomic nervous system (ANS) responses (such as heart rate) and neurophysiological responses (such as brain activity) originate from medicine and have only recently been applied in consumer and sensory research. Three key reasons might explain why few studies use implicit methods: the multidisciplinary character, the amount of training and the interpretation of the data. Although food research tends to be multidisciplinary, few teams include a field where implicit methods are common-place in research. Furthermore, when looking into setting up these implicit methods, finding colleagues of other fields is challenging and time-consuming. Similarly time-consuming is the amount of training required to set up and perform measurements according to an implicit method. Lack of experience, material and the many requirements to obtain valid results call for extensive training. Finally, the data obtained are not as self-explanatory as in explicit research. Data needs many transformations to be readable for researchers. As the data is gathered continuously, datasets are very big and need to be filtered and split. Again, time and effort need to be invested (Dorado, et al., 2016b). Despite those challenges, implicit measurement of emotion (in particular expressive and physiological measures) in sensory and consumer research is on a rise as they are increasingly understood by researchers. Looking to the publication years of the reviewed studies, the number of studies using an implicit measurement (expressive and physiological measures) and the number of studies using both explicit and implicit measurement has increased over the last 3 years.

Within the implicit measures expressive measures, in particular registration of facial expressions, are the most popular. Facial expression measurement was typically carried out using computer software which automatically detects changes of the human facial expression to different emotions (Tian, Kanade, & Cohn, 2005). However, in the case of tasted food the registration of facial expressions is often disturbed by facial movements when chewing of solid foods. This seriously hampers the registration of emotional responses during the consumption of food products. Therefore facial expression registration is the most useful in case of food names instead of tasted foods (Koster & Mojet, 2015). Also for measurements of ANS responses studies have used drinks, such as breakfast drinks (de Wijk, et al., 2014) or solutions, such as bitter and sweet solutions (Samant, Chapko, & Seo, 2017), to account for movement artifacts in the data.

Whereas explicit measures cover mostly a large number of emotions, implicit measures generally cover a small number of emotions. For facial expression measurement emotions are limited to the six basic emotions (Ekman, 1993) as physiological measures have been shown unable to distinguish among a large number of different, especially positive, emotions (Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008). The emotion specificity for ANS response measurements is debated. Some suggest a dimensional approach, such as valence and arousal dimensions, while others proposed discrete emotions (for a review on ANS measures, see Kreibig (2010)).

The combination of an implicit measurement and an explicit measurement was performed in six of the reviewed studies. When combining both methods it is important to understand that most implicit measures, such as facial expression and physiological responses, provide a continuous measurement, whereas explicit measures, such as the emotional lexicon, provide discrete information at a certain point in time about emotional responses elicited by the food product.

The comparison of explicit and implicit measures to demonstrate the convergent validity, has not been done in sensory and consumer research until recently in Samant, et al. (2017). This recent study compared facial expression measurement and measurements of autonomic nervous system responses to the self-reported emotional lexicon (EsSense25). The results showed that emotional responses measured using EsSense25 and facial expression analysis along with perceived taste intensity performed best to predict overall liking as well as preference, while ANS measures showed limited contributions (Samant, et al., 2017). However, ANS measurements have been used a lot in psychology to assess emotional response to stimuli and are considered the major component of the emotion response in many theories of emotion (Kreibig, 2010). Some researchers suggest ANS measures can be used for measures of arousal or valence (Fernández, et al., 2012). Although individual ANS measures appear responsive to dimensions (such as arousal) rather than discrete emotional states. Kreibig, Wilhelm, Roth, and Gross (2007) found that the combination of 11 ANS measures differentiated responses to fear-inducing versus sadness-inducing film clips with 85% accuracy. Nevertheless, the emotion specificity is debated and is likely to depend on the nature of the stimuli (for a complete review on ANS measures, see Kreibig (2010)). Findings in food research show mixed results as they are concerned with product development questions with specific products or product attributes (Danner, et al., 2014a; de Wijk, et al., 2014; de Wijk, et al., 2012; He, et al., 2016). Therefore, replications of studies are needed and it will be increasingly important to compare the results of implicit and explicit measurements.

Although flavor dominates as a stimulus in the reviewed studies, it seems that a focus on flavor alone is not sufficient to measure the complete consumer experience as different stimuli (flavor, food name or image) may elicit different kinds and degrees of emotions. Some studies experimented with food images to measure emotions associated with the product without tasting. Cardello, et al. (2012) showed a greater emotional response towards food name than towards the product flavor. They concluded that food names may elicit memories of an emotional experience with food whereas the product flavor may not elicit this strong experience. Tasted foods can vary over time in emotional response due to perceptual variability, changing expectations and preceding appetitive contexts (Cardello, et al., 2012). A parallel can be drawn with timing. Most studies, especially when explicit methods are used, measured emotion after sensory perception. As such the method does not measure a natural state or baseline which can account for individual differences. An appetitive context or an overall negative feeling of the day can change reported perception of the emotion. In the latter example a negative feeling could weaken a positive emotion or strengthen a negative one. Implicit methods apply a continuous monitoring of emotion measurement which means a baseline is inherent in the approach. Explicit methods could on the other hand include a baseline measurement to access the mood of the participant before consumption. Explicit methods could on the other hand include a baseline measurement to evaluate the mood of the participant before consumption. Furthermore, the question arises of a general baseline measurement of the mood is sufficient as performed by Danner, et al. (2016) or that the same emotional terms or visual representations of the emotions should be used. The latter enables a more thorough overview of the state of mind of each individual's mood when participants evaluate the products while a more general baseline measurement might shorten response time and have a smaller overall impact on the actual mood of the participant.

For explicit methods most often products with high consumer acceptance levels that are often linked to emotion were selected for research. Snack products and especially chocolate were frequently used. When measuring emotions in a recall survey, Desmet and Schifferstein (2008) noted specific emotions for main meal, followed by sweet snacks, alcoholic drinks, chocolate and meat. King and Meiselman (2010) found that chocolate and pizza elicited the strongest emotional associations among participants. In contrast, foods like oatmeal and carrots elicited less emotional associations and are only rarely used in the studies reviewed. When comparing implicit and explicit methods, implicit methods more frequently choose products with low consumer acceptance levels. As such, it can be deduced that researchers assume that emotions elicited by high accepted products are easier to express or scale explicitly and that emotions elicited by low accepted products can be registered implicitly more easily as the body would react more strongly to negative stimuli.

Young adults, mostly women, were most often chosen as study population in the reviewed studies. Women are shown to be more emotionally sensitive to food than men, although this is food specific and reversed for some products (King, et al., 2010). Those differences may be associated with gender role, where females tend to express emotions more than men (Kring & Gordon, 1998). Not only for expressed emotion, but also in autonomic nervous system (ANS) responses gender differences are noted (Gomez, von Gunten, & Danuser, 2016). Women's ANS responses revealed enhanced reactivity to unpleasant arousing pictures, whereas men's ANS responses revealed enhanced reactivity to pleasant arousing pictures. Gomez, et al. (2016) also noted age differences in emotional processing and in basic autonomic nervous system functioning. A decrease in the strength of heart rate, skin conductance level and pupil size are shown from younger to older age. Age-related factors, such as physiological changes and medication use, also seem to make it more difficult to measure implicit emotions of older consumers through ANS responses or reaction time (den Uijl, et al., 2016; Kunzmann, Kupperbusch, & Levenson, 2005; Neiss, Leigland, Carlson, & Janowsky, 2009). Also for self-reported measures, age should be considered as an important factor. In a recent study of den Uijl, et al. (2016) older adults scored negative emotions lower in comparison to younger adults. The authors concluded that this age-related positive orientation extends to the rating of food-elicited emotions and even to the emotional experience of the food products. Besides, older individuals seem to use their recalled emotional experiences with the products, rather than their actual elicited emotion (Koster & Mojet, 2015; Thomson, et al., 2010). Hence, age should be considered as an important factor when explicit or implicit measurements are used to assess product-elicited emotions and further research is needed to determine the suitability of the measurement or response format (e.g. CATA versus RATA) for specific consumer groups. Specific instruments should be developed for specific consumer groups, e.g. children compared to elderly.

Most of the tests have been carried out in sensory facilities as researchers wanted to control the environmental factors as much as possible (Meilgaard, Carr, & Civille, 2006). Although tests carried out in a sensory laboratory setting are easier to compare when taken place in different locations (e.g. different regions or countries) and on different occasions, this consumption context does not resemble actual food consumption leading to questions regarding the ecological validity (Schmuckler, 2001) of the tests. A series of studies illustrated that when people are thinking about an imaginary consumption setting, the explicit emotional profiling of food products is influenced (Piqueras-Fiszman & Jaeger, 2014a, 2014b, 2014c). A study of Dorado, et al. (2016a) has used a written scenario to ensure a more realistic environment. Some other studies have simulated a more real-life environment by testing for example in a kitchen (Labbe, et al., 2015), lounge setting (Bhumiratana, et al., 2014) or a simulated restaurant or cafeteria setting (Dalenberg, et al., 2014; Gutjar, et al., 2015a). A study performed by Danner, et al. (2016) found that tasting wine in the restaurant context evoked more intense positive emotions compared to the home and laboratory contexts. Another recent study found that the emotional associations of yoghurt samples differed between a laboratory and home context (Schouteten, De Steur, Sas, De Bourdeaudhuij, & Gellynck, 2017a). Possible reasons why context effects on emotional conceptualizations are observed are the social component and the combination with other food products. In the study of Danner et al. (2016) for example, social interaction, talking and additional food consumption was allowed in the restaurant context and at home the participants were free to taste the wines in combination with food, alone or in company.

For implicit measurements, the test always took place in a controlled test setting, where each participant was tested separately in an individual room or booth, as measurements of facial expressions or physiological measures are technically more challenging than a questionnaire. Hence, implicit measurements are more suitable for laboratory environments than for real-life (de Wijk, et al., 2014).

Technological advancements should make it possible in the near future to carry out tests in an immersive or virtual context. This would make it possible to have the best of two worlds: product-elicited emotions measured in a laboratory context under controlled circumstances although participants have the feeling they are consuming the food samples in a more realistic consumption context such as at a bar or restaurant.

The focus on consumer and sensory studies which included both sensory preference and emotional measurements of food products hampers the generalizability to the broad emotion research field in particular. This review also did not evaluate the results generated by the different approaches and the impact of sample characteristics on emotional response to food is not further explored through for example meta analysis.

Future research could review the results generated by the different approaches in order to compare and evaluate them, starting from the overview of the approaches in this review. Challenges in consumer and sensory research include the development of a more complete understanding of drivers of consumers' preferences and hedonic liking (Leitch, et al., 2015). Traditional consumer and sensory research is focused on explicit methods of sensory and emotional perceptions through questionnaires and emotional lexicons in a primarily young adult population in developed countries (especially countries in Europe and USA). Future research would benefit from additional instruments complementary to the existing ones (Gutjar, et al., 2015a). Implicit methods are an emerging tool to measure emotion in relation to food and may bring additional support to traditional sensory research for a better understanding of emotional response to food (Walsh, et al., 2017b). The use of implicit methods can also help to broaden the research range from products with high to products with low consumer acceptance levels. Furthermore, future research could expand to developing regions and broaden the sample population to various consumer groups.

This review has aimed to present the state of the art with respect to consumer and sensory research by evaluating and mapping research methods, measurements and instruments in the increasingly interdisciplinary field that is trying to capture the total consumer experience when examining the relationship between food and consumer. While this field of research is rapidly growing (as recent research beyond this study shows, e.g. Beyts, et al. (2017); Jaeger, et al. (2017a); Jaeger, Vidal, Kam, and Ares (2017b); Walsh, Duncan, Bell, O'Keefe, and Gallagher (2017a); Walsh, et al. (2017b)), this systematic review offers a comprehensive overview of the different methods, measurements and instruments to capture emotional associations. The review may prompt researchers to consider measuring the total consumer experience by building appropriate research designs including innovative approaches like interdisciplinary implicit methods.

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PART II:

EXPLICIT MEASURES OF SUBJECTIVE FOOD PRODUCT QUALITY AND FOOD PRODUCT-ELICITED EMOTIONS

Chapter 3
A comparison between two low-calorie sweeteners and sugar in dark chocolate on sensory attributes and emotional conceptualizations

This chapter is based on:

Lagast, S., De Steur, H., Schouteten, J. J., & Gellynck, X. (in press). A comparison of two low-calorie sweeteners and sugar in dark chocolate on sensory attributes and emotional conceptualizations. *International Journal of Food Sciences and Nutrition*.
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Abstract

Reducing sugar consumption is an important aspect in the prevention of and fight against obesity. A broader understanding of consumers' perceptions of low-calorie sweeteners is needed. This study examined two low-calorie sweeteners, tagatose and stevia, in comparison to sugar in dark chocolate. A total of 219 consumers participated in this study and rated overall liking and sensory attributes. Participants also listed their emotional conceptualizations upon consumption and were assessed on emotional eating behavior and health and taste attitudes. The chocolate with tagatose was perceived as more similar to the chocolate with sugar than with stevia on overall liking, texture, bitterness, duration of aftertaste and intensity of aftertaste. Furthermore, chocolate with sugar and chocolate with tagatose both elicited positive emotional conceptualizations whereas chocolate with stevia elicited negative emotional conceptualizations. In conclusion, dark chocolate with tagatose did not significantly differ from sugar in overall liking, most sensory attributes and emotional conceptualization.

Research question 2: How does a more positive, explicit verbal emotional conceptualization profile discriminate between dark chocolates?

RQ2a *How do the overall liking scores and the sensory profiles differ for dark chocolates with two low-calorie sweeteners in relation to dark chocolate with sugar?*

RQ2b *In what manner do the explicit verbal emotional conceptualizations discriminate between dark chocolates with different low-calorie sweeteners?*

RQ2c *To what extent is consumers' emotional eating behavior related to emotional conceptualizations of dark chocolates?*

RQ2d *To what extent are consumers' health and taste attitudes related to acceptance of dark chocolates?*

3.1 Introduction

Reducing consumption of sugar levels in the world's population is a key to improving public health by preventing and tackling obesity. In 2015 the World Health Organization launched a directive to limit sugar intake to 25 grams per day (World Health Organization, 2015). This has led to an increased awareness among consumers about the risks of high sugar intake and to a more prominent role of low-calorie sweeteners in the market (Ghosh & Sudha, 2012; Goyal & Goyal, 2010).

The replacement of sugars with low-calorie sweeteners is a way to lower sugar intake and to manage body weight (Anderson, Foreyt, Sigman-Grant, & Allison, 2012; Bellisle & Drewnowski, 2007; Drewnowski & Rehm, 2014; Gardner et al., 2012; Ludwig, 2009). People who consume low-calorie sweeteners tend to have higher health eating index scores and tend to be more physically active as well (Drewnowski & Rehm, 2014). The combination of consumption of low-calorie sweeteners with healthier diets and with more physical activity is even more effective in reducing and controlling body weight (Bellisle et al., 2001; Bleich, Wolfson, Vine, & Wang, 2014). Low-calorie sweeteners can thus contribute to promoting healthier public nutrition and are particularly helpful for certain consumer groups such as patients with diabetes, people who want to decrease caloric intake and children (Goyal & Goyal, 2010).

However, low-calorie sweeteners will only be accepted by a broad base of consumers if their sensory attributes are positively evaluated. Sensory liking remains the main driver for preference and food choice (de Graaf et al., 2005; Hellemann & Tuorila, 1991; Hetherington & Macdiarmid, 1995). Therefore, it is important that the products with a lower calorie content resemble the original product on sensory attributes (Zorn, Alcaire, Vidal, Giménez, & Ares, 2014). Unfortunately, some low-calorie sweeteners elicit undesirable sensory qualities such as unpleasant aftertaste, bitterness, metallic taste or astringency (Fujimaru, Park, & Lim, 2012) which can be linked to a lower consumer acceptance (Zhao & Tepper, 2007). Stevia, for example, elicits lower liking scores in mango nectar, grape nectar, skimmed chocolate milk and chocolate compared to sugar (Cadena et al., 2013; de Melo, Bolini, & Efraim, 2009; Li, Lopetcharat, & Drake, 2015; Shah, Jones, & Vasiljevic, 2010; Voorpostel, Dutra, & Bolini, 2014) and shows non-sweet off flavors (bitterness and black liquorice) with high stevia levels (Prakash, DuBois, Clos, Wilkens, & Fosdick, 2008). Tagatose, on the other hand, has been shown to have similar physical and sensory characteristics as sugar and to elicit sweet flavor without undesirable qualities in aqueous solutions (Fujimaru et al., 2012).

Not only sensory acceptance is important, it is also essential to measure beyond acceptance by assessing a broader insight in consumers' food product experience (Cardello et al., 2012; Thomson, Crocker, & Marketo, 2010). In consumer research, the role of emotion in behavior has been increasingly acknowledged (Johnson & Stewart, 2005). Recent studies show that consumers' emotional conceptualizations towards food products can add information beyond overall acceptance (Cardello et al., 2012; Coleman, Miah, Morris & Morris, 2014; Gutjar et al., 2015; King & Meiselman, 2010; Ng, Chaya, & Hort, 2013; Schouteten et al., 2015; Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014; Thomson et al., 2010). Several studies have illustrated that emotional conceptualizations can discriminate between food products even if the overall acceptance between products is similar (King & Meiselman, 2010; Ng, et al., 2013a; Spinelli, et al., 2015). In order to capture more information about consumers attitudes towards food products emotional conceptualizations have been assessed (Jiang et al., 2014; Meiselman, 2015, Thomson, 2007).

To assess the emotions elicited by food, most studies use a self-reported method. The most commonly used method is a questionnaire format with a list of emotional terms (emotional lexicon) that can be checked (e.g. Check-all-that-apply, CATA) or rated. The emotional lexicon typically holds terms that can be classified as positive or negative (Desmet & Schifferstein, 2008; Schifferstein & Desmet, 2010; Schouteten et al., 2015) and can be either standardized or consumer-generated. Standardized emotional lexicons such as the EsSense Profile® questionnaire have been developed by King and Meiselman (2010). Consumer-generated lexicons are product-specific and have already been applied to a wide range of foods, such as chocolate (Thomson et al., 2010), hazelnut spreads (Spinelli et al., 2014), fruit salads (Manzocco, Rumignani, & Lagazio, 2013) and cheese (Schouteten et al., 2015). Recently, also non-self-reported (implicit) measurements of emotions have gained attention. Researchers have used psychophysiological response tracking, such as facial expressions, skin conductance, heart rate or finger temperature of consumers, to access implicit emotions (de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014; de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012; Leitch, Duncan, O'Keefe, Rudd, & Gallagher, 2015; Pentus, Mehine, & Kuusik, 2014).

Some studies have even aimed to attribute distinct emotions to sensory attributes. Robin, Rousmans, Dittmar & Vernet-Maury (2000) for example asked participants to associate emotions (happiness, surprise, sadness, fear, disgust and anger) with water solutions of basic flavors (sweet, sour, bitter and salt). The sweet solution was mainly associated with happiness and surprise, the bitter one with anger and disgust, and the salty and sour solutions were associated with all emotions.

This study uses dark chocolate as a case. Chocolate is high in sugar content and has a hedonic appeal due to its composition and sensory attributes (fat, sugar, texture and aroma) (Bruinsma & Taren, 1999). Emotions associated with chocolate consumption have been both positive and negative. Mach and Dettmer (2006) demonstrated that women experience both joy and guilt after consuming chocolate. Joy was elicited by the sensory pleasure of eating chocolate, while guilt appeared to be induced by negative thoughts associated with it (like the unwanted effect on body weight). In attempts to address consumers' demands to reduce sugar intake through chocolate, sugar is increasingly substituted by sweeteners. Yet, for long-term consumption of low-calorie chocolate, there is a need to examine consumer-acceptance of low-calorie sweeteners (Li et al., 2015).

In this study consumers' sensory evaluation and emotional conceptualizations upon consumption of dark chocolates with sugar and two low-calorie sweeteners (tagatose and stevia) are investigated. The study aims to compare two low-calorie sweeteners in relation to sugar in dark chocolate (1) by examining the overall liking and sensory attributes of the chocolates, (2) by investigating which emotional conceptualizations consumers associate with the chocolates and (3) by looking at how consumers' emotional eating behavior and health and taste attitudes are related to acceptance and emotional conceptualizations.

3.2 Materials and methods

Participants

Participants were recruited at the university campus by poster advertisement and were also recruited from a database containing volunteers for sensory and consumer research of Ghent University. In total, 219 consumers participated voluntarily and completed the questionnaire anonymously via EyeQuestion v 3.12.0 software (Logic8 BV, Elst, The Netherlands). Testing took place in the sensory facilities of Ghent University and participants evaluated the samples in sensory booths. Because this study focused on the sweeteners used in chocolate, i.e. through comparing two low-calorie sweeteners in relation to sugar in dark chocolate, this study has recruited participants that consume all types of chocolate (white, milk and dark) regardless of their chocolate preference. Yet, to be eligible for participation participants were required to like and consume all three types of chocolate. They were barred from participation if they had any food allergies or if they disliked dark chocolate. This screening was operatized through two questions, one for acceptance of chocolate and one for food allergies.

Samples

Three dark chocolates were selected for consumer evaluation: chocolate sweetened with tagatose (Damhert dark, Belgium), chocolate sweetened with stevia (Cavalier dark, Belgium) and chocolate with sugar (Jacques dark, Belgium). Based on previous suggestions for emotional research by King, Meiselman and Carr (2013) the number of samples was limited to three. All chocolates were commercially available in Belgian supermarkets and all contained a minimum cacao percentage of 50%. The chocolates with sweeteners still contained naturally occurring sugars, respectively 0.3 and 3.2 gram of sugars per 100 gram of chocolate for the chocolate with tagatose and the chocolate with stevia. Additionally, the chocolate with stevia contained erythritol which is a bulking agent that also suppresses the bitter flavor of stevia. Table 3.1 gives an overview of the key characteristics of the chocolates. In appendix B a more detailed overview of the nutritional values and the ingredient list for each chocolate can be found.

A piece of approximately 3.33 grams of each chocolate was presented to the participants at the same time. All chocolates had the same shape and no brand information was visible on the chocolate pieces. A random 3-digit number was assigned to each sample to reduce expectation errors (Moskowitz, Beckley, & Resurreccion, 2012). Moreover, the chocolates were evaluated in a random order to prevent first-order and carryover effects.

Table 3. 1 Key characteristics of the examined chocolate products expressed per 100 grams of chocolates

Product	Cocoa (min %)	Nutritional value (kcal)	Sugar (g)	Polyols (g)
Chocolate + sugar	50	520	46.9	0.0
Chocolate + tagatose	54	457	0.3	3.6
Chocolate + stevia	55	432	3.2	8.7

Note: all values are expressed per 100 g of chocolate.

Procedure

Participants were invited to the sensory facilities of the university. They were told they would be evaluating three pieces of dark chocolate but no information of sugar or sweetener content was given.

Before starting the questionnaire participants needed to complete two screening questions in order to assess their eligibility for the study. The screening criteria were based on their diet (liking and consumption of chocolate) and food allergies (no allergy for chocolate, no allergy for nuts, no allergy or intolerance for lactose and no allergies for other food products).

The questionnaire consisted of three sections: (1) attitude and behavior (health and taste attitudes related to food, chocolate eating behavior and emotional eating behavior); (2) overall liking, sensory attributes and emotional conceptualizations of the three selected chocolates; and (3) socio-demographic profile and diet restriction behavior of the participant (diet to lose weight). The flow of the screening and questionnaire is depicted in Figure 3.1.

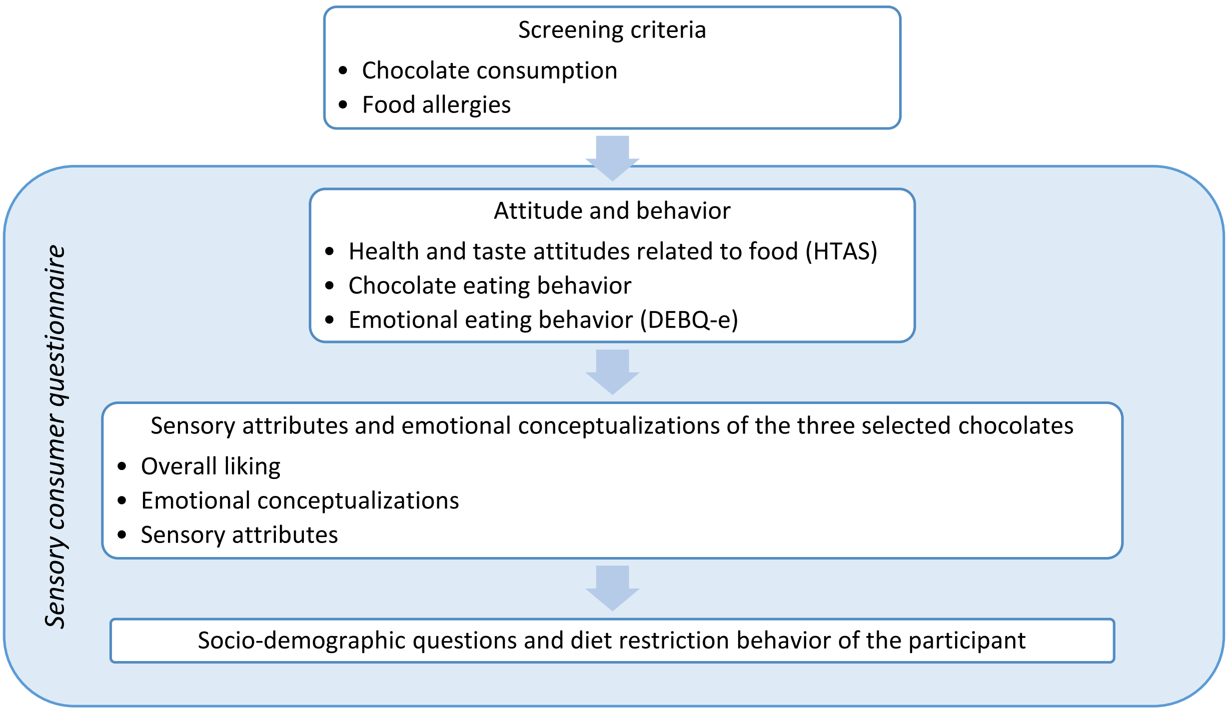

Figure 3. 1 Screening and questionnaire flow

The first section of the questionnaire examined the participant's *attitudes and behavior*. To gain more information about the health and taste interests of the participants, health and taste attitudes were measured by the Health and Taste Attitude Scale (HTAS), a validated questionnaire, developed by Roininen, *et al.* (2001). This scale measures the importance of health and taste in foods in the food choice process. It consist of three health sub-scales (general health interest, light product interest and natural product interest) and three taste sub-scales (craving for sweet foods, using food as reward and pleasure). The 20 items on health and 18 items on taste had to be rated on a 7-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7).

Behavior was measured by questions about chocolate eating behavior and emotional eating behavior. Chocolate eating behavior was examined with questions based upon a focus group discussion, prior research and literature review. The preference of type of chocolates was measured using 3 categorical labels: white, milk and dark. The frequency of consumption was examined using 5 categorical labels ranging from "daily" to "less than once in two weeks". Emotional eating behavior was examined by the emotional eating scale of the validated Dutch Eating Behavior Questionnaire (DEBQ-e) (Van Strien, Frijters, Bergers, & Defares, 1986). The DEBQ is a validated psychometric construct which measures three types of eating behavior: emotional eating, external eating and restricted eating. In the present study, only the 13 relevant items on emotional eating were implemented in the questionnaire as a 5-point scale (from "never" to "very often").

In the second part participants received three pieces of dark chocolate at the same time, one of each type of chocolate. In a randomized order, participants evaluated one piece of dark chocolate at a time. Participants were instructed to take a first bite of the chocolate and (1) rate the overall liking using a 7-point bipolar scale (ranging from 1 = extremely dislike to 7 = extremely like); and (2) select the applicable emotional terms with the following instruction: "Below you find a list of terms that describe emotion. Using the list below, tick each word that describes how you feel right now. Please tick all terms that are applicable." This instruction was based upon previous work of emotional profiling of food products (King & Meiselman, 2010). Next, participants were instructed to take a second bite and were asked to rate sensory attributes, namely texture and taste (sweetness, bitterness, intensity of aftertaste and duration of aftertaste) on a 5-point just-about-right (JAR) scale.

The last part contained questions regarding the socio-demographic status of the respondents (gender and age (categorical), and weight and length (continuous)) and diet restriction behavior to lose weight (currently on a diet to lose weight, on a diet to lose weight during the last year or none of both).

Development of consumer defined emotional lexicon

A product specific emotional lexicon was determined during preliminary research following a two-step approach suggested by Ng, et al. (2013). First, a group of 17 healthy and young adults (10 females, 7 males, 82% between 18-34 years) evaluated a list of emotional terms based on literature (Desmet & Schifferstein, 2008; King & Meiselman, 2010; Thomson & Crocker, 2013). Second, a final selection was made based on the frequency of the terms selected (20%) and the ability of the terms to discriminate between food products (De Pelsmaeker, Schouteten, & Gellynck, 2013; Ferrarini et al., 2010; Manzocco et al., 2013; Ng et al., 2013; Thomson et al., 2010). Additionally, a balance between positive and negative emotions was made to enhance a more natural balance between the amount of positive and negative emotional conceptualization for food products (De Pelsmaeker et al., 2013; Desmet & Schifferstein, 2008; King & Meiselman, 2010). Based on these results 24 emotional terms comprised the actual list (Table 3.2).

Table 3. 2 Overview of the selected emotional conceptualization terms

Emotional conceptualization term	
Positive	Negative
Feeling good	Anger
Pleased	Disappointment
Happy	Unpleasant surprise
Glad	Bored
Satisfying	Dissatisfying
Interesting	Sad
Enjoyment	Quiet
Calm	Disgusted
Active	Tame
Joyful	
Peaceful	
Stimulating	
Pleasant	
Enthusiastic	
Good-natured	

Data analysis

Statistical analyses were performed using SPSS Statistics 22. To assess the difference in overall liking and sensory attributes among chocolate samples, repeated measures ANOVA tests were performed. Bonferroni or Dunnett post-hoc tests were executed to look at differences between the three samples, in case of homogeneity or non-homogeneity of variance, respectively.

To compare emotional conceptualizations and different types of chocolates, a Cochran's Q test was executed for each emotional term. Pairwise comparison between three different chocolates for each emotional term was achieved using the McNemar Test. As emotional conceptualizations were measured through a CATA question, correspondence analysis was used in order to make a graphical presentation. All emotional conceptualizations were plotted together with the three types of chocolate and overall liking was added as a supplementary category.

Factor analysis (Maximum likelihood with Varimax rotation) was performed on the items of the Health and Taste Attitude Scale (HTAS) (separately on the 20 health and 18 taste items) and on the 13 items of the emotional eating scale of the Dutch Eating Behavior Questionnaire (DEBQ-e). Cronbach's alpha was then used to test the internal reliability of each factor. Means and standard deviations of the factors of the health and taste attributes and emotional eating behavior were calculated.

For differences in mean liking by socio-demographics, eating behavior and attitudes, mixed factorial ANOVA tests was performed. Depending on the homogeneity or non-homogeneity of variance of samples, respectively, Bonferroni or Dunnet post-hoc tests were used. Mean overall liking was used as a within-subjects variable and socio-demographics, eating behavior and attitudes as between-subjects variable for each chocolate sample.

Finally, to link the emotional profile in response to the consumption of the chocolates and the emotional eating behavior, the participants were segmented into three groups according to their DEBQ-e score. The split was performed by characterizing participants as being low emotional eaters, medium emotional eaters and high emotional eaters using the clinical norm scales for healthy populations taking gender and BMI into account. The amount of participants in these groups was 17, 120 and 82 respectively. The same methodology was used as in Piqueras-Fizman & Jaeger (2014) to link emotional responses to emotional eating. The segmentation in three groups created an uneven group of participants, however the results were interpreted with caution in instances where the number of participants was very unbalanced.

3.3 Results

Socio-demographic profile

Participants' socio-demographics are displayed in Table 3.3. The questionnaire was completed by 219 consumers of which 92 men (42%) and 127 women (58%). Of all participants, 68% were high chocolate users (with an everyday or more than once a week consumption of chocolate). Milk chocolate was the most consumed and preferred type of chocolate. The main motivation to eat chocolate was craving, followed by taste. Half of the participants had a moderate emotional eating behavior (54.8%) and high emotional eaters accounted for 37.4%. In this case, 82 participants were highly influenced by emotions in their eating behavior (Table 3.3).

Table 3. 3 Socio-demographics and eating behavior of participants

Socio-Demographics	n	%	***Eating behavior***	n	%
			Chocolate consumption		
Gender			Frequency		
Male	92	42	High users	147	68
Female	127	58	Medium users	45	20
Age			Low users	27	12
18-25 years	128	58	Consumption		
26-45 years	41	19	White	12	6
46+ years	50	23	Milk	127	58
BMI (mean = 22.44, SD = 3.12)			Dark	80	36
Underweight (<18.5)	17	8	Preference		
Normal weight (18.5-25)	158	74	White	27	12
Overweight (> 25)	40	19	Milk	107	49
Currently on a diet to lose weight			Dark	85	39
No	202	92	Motivation		
Yes	17	8	Taste	134	42
On a diet to lose weight during last year			Emotional	23	7
No	185	85	Craving	151	48
Yes	34	15	Habit	28	9
			Reduce feelings of hunger	23	7
			Else	12	4
			Emotional eating behavior		
			Low	17	7.8
			Moderate	120	54.8
			High	82	37.4

Note: participants could check more than one option for motivation (n=371). Eating behavior was measured through 13 items of the Dutch eating behavior questionnaire (DEBQ-e) (Van Strien et al., 1986) on a 5-point Likert scale (1 = never, 5 = very often). Raw scale score was compared to norm scales according to BMI and gender. These were categorized as follows: very low to low = low, under average, average and above average = moderate, high and very high = high

Overall liking and sensory profile

The overall liking differed significantly between the selected chocolate samples (Table 3.4). Bonferroni Post-Hoc test showed a significant lower overall liking for chocolate with stevia compared to chocolate with tagatose and compared to chocolate with sugar. No significant differences were found between chocolate with sugar and chocolate with tagatose.

Regarding the sensory attributes, chocolates with low-calorie sweeteners tagatose and stevia differed significantly on texture, sweetness, bitterness and duration of aftertaste. Yet, the chocolate with tagatose did not differ from the chocolate with sugar on texture, bitterness and duration of aftertaste. The results show that chocolate with tagatose approximates the chocolate with sugar. The use of stevia leads to the largest differences with chocolate with sugar.

Table 3. 4 Evaluation of overall liking and sensory attributes of chocolates with sugar or low-calorie sweeteners

	Regular		**Low-calorie sweeteners**					
	Chocolate + sugar		**Chocolate + tagatose**		**Chocolate + stevia**			
	Median	Q1-Q3	Median	Q1-Q3	Median	Q1-Q3	F-value	p-value
Overall liking	5[a]	4-6	5[a]	3-6	3[b]	2-4	85.80[*]	0.000
	Mean	SD	Mean	SD	Mean	SD	F-value	p-value
Sensory attributes								
Texture	0.02[a,b]	0.57	-0.06[a]	0.63	0.12[b]	0.66	6.72[***]	0.001
Taste								
- Sweetness	0.15[a]	0.73	-0.16[b]	0.77	-0.73[c]	0.87	100.10[***]	0.000
- Bitterness	-0.23[a]	0.71	0.10[a]	0.79	0.29[b]	1.05	33.60[***]	0.000
Aftertaste								
- Intensity	-0.05	0.68	-0.10	0.75	0.07	1.07	2.91	0.058
- Duration	-0.04[a]	0.71	-0.05[a]	0.77	0.24[b]	0.94	10.53[***]	0.000

Repeated measures ANOVA with Bonferroni post-hoc tests, [ab] significantly different (p≤0.05). Overall liking measured on 7-point bipolar scale ranging from 1 (extremely dislike) to7 (extremely like), sensory attributes measured on 5-point just-about-right scale ranging from -2 (e.g. not sweet enough) to 2 (e.g. too sweet),
[*] significance p<0.05, [***] significance p<0.01.

Emotional conceptualizations

Significant differences for the frequency of use among the different types of chocolate were found for 14 emotional terms, 10 positive and 4 negative. Positive emotional conceptualizations are more associated with chocolate with sugar and chocolate with tagatose. 'Feeling good' and 'pleased' have the highest values for chocolate with sugar and chocolate with tagatose. The positive emotional conceptualization 'feeling good' is more discriminating between the low-calorie sweeteners tagatose and stevia and the positive emotional conceptualization 'pleased' is more discriminating between sugar and low-calorie sweetener stevia. Negative emotional conceptualizations are mostly associated with chocolate with stevia. In particular, negatively loaded emotions, such as 'disappointment', 'dissatisfaction', 'unpleasant surprise' and 'disgusted' are significantly more stated when consuming chocolate with stevia. The negative conceptualization 'unpleasant surprise' showed the biggest difference between the low-calorie sweeteners and the negative emotional conceptualization 'disappointment' showed the biggest difference between sugar and low-calorie sweetener stevia. Values of the emotional conceptualization can be found in Table 3.5.

Table 3. 5 Comparison of emotional conceptualizations of chocolate with tagatose and stevia in relation to chocolate with sugar. Significant differences in frequency of emotional conceptualizations (%) (n=219)

		Regular	**Low-calorie sweetener**		**Sub-sample differences**	
		Chocolate + sugar	**Chocolate + tagatose**	**Chocolate + stevia**		
		%	%	%	Cochran's Q	p-value
Positive	Feeling good	**47.49**[a]	**48.86**[a]	30.14[b]	27.49***	0.000
	Pleased	**45.66**[a]	**40.18**[a]	23.74[b]	32.84***	0.000
	Calm	43.38	42.47	35.16	5.36	0.069
	Interesting	**29.68**[a]	**27.85**[a]	18.72[b]	11.81***	0.003
	Pleasant	**29.22**[a]	**26.03**[a]	11.42[b]	30.88***	0.000
	Satisfying	27.40[a]	19.63[b]	12.79[c]	19.72***	0.000
	Happy	**24.20**[a]	**26.48**[a]	17.35[b]	10.31***	0.006
	Glad	**24.66**[a]	**25.57**[a]	11.87[b]	24.46***	0.000
	Peaceful	23.29	21.46	17.35	3.75	0.154
	Good-natured	**18.72**[a]	**21.00**[a]	11.87[b]	11.61***	0.003
	Enthusiastic	**14.16**[a]	**15.53**[a]	6.85[b]	12.28***	0.002
	Enjoyment	12.79	13.24	8.68	3.64	0.162
	Joyful	12.33	15.53	11.87	2.43	0.297
	Stimulating	**10.05**[a]	**10.05**[a]	2.74[b]	12.80***	0.002
	Active	5.94[a,b]	9.59[a]	4.57[b]	6.93***	0.03
Negative	Disappointment	8.22[b]	12.79[b]	**34.25**[a]	60.41***	0.000
	Unpleasant surprise	10.05[b]	9.13[b]	**31.96**[a]	55.91***	0.000
	Dissatisfying	8.22[b]	11.87[b]	**27.85**[a]	41.29***	0.000
	Disgusted	5.48[b]	4.11[b]	**15.98**[a]	27.59***	0.000
	Tame	9.59	12.79	14.16	4.16	0.125
	Quiet	16.44	13.24	13.24	2.33	0.311
	Bored	5.48	7.76	10.05	4.29	0.117
	Sad	3.20	3.65	5.02	1.44	0.489
	Anger	2.74	2.28	3.65	1.00	0.607

***P<0.01, Repeated measures ANOVA, [abc] Row indicates which sample are significantly different (p≤0.05) from each other on the emotional conceptualization. Each chocolate sample with different letters is significantly different (p≤0.05). No letter in row indicates that the emotional conceptualization is not significantly different. Bold numbers refer to the highest significant percentage in rows

A graphical presentation of the correspondence analysis of the emotional conceptualizations on two dimensions is shown in Figure 3.2. Chocolate with tagatose and chocolate with sugar were situated on the side where positive emotional conceptualizations dominate (left side). In contrast, chocolate with stevia was situated on the side where negative emotional conceptualizations are situated (right side). To have a visual representation of how liking is associated with the emotional conceptualizations, overall liking was added as a supplementary category. This did not affect the configuration of the emotional conceptualization and the orientation of the axes. On the right side of the plot negative overall liking is situated and on the left side positive overall liking is displayed. Negative overall liking was associated with negative emotional conceptualizations as well as with chocolate with stevia. Positive overall liking was associated with positive emotional conceptualization as well as with chocolate with tagatose or sugar. Mapping of the emotional terms in a semantic space as proposed by Spinelli *et al.* (2014) showed that sugar and tagatose were situated together on the valence dimension (positive – negative), but appeared to be slightly different on the activation dimension (low-high arousal). Chocolate with tagatose was situated at the high arousal (higher activation) side of the dimension and chocolate with sugar at the low arousal (lower activation) side. This means that chocolate with sugar and chocolate with tagatose were associated with different types of positive emotional conceptualizations. Chocolate with sugar was linked to the emotional conceptualizations ‘pleased’ and ‘pleasant’, whereas chocolate with tagatose was related to ‘enthusiastic’ and ‘joyful’. As shown, valence positively correlated with liking, but activation was not that straightforwardly related to liking. For the chocolate with stevia there was no difference on the arousal dimension, as it is situated at the midline of the dimension.

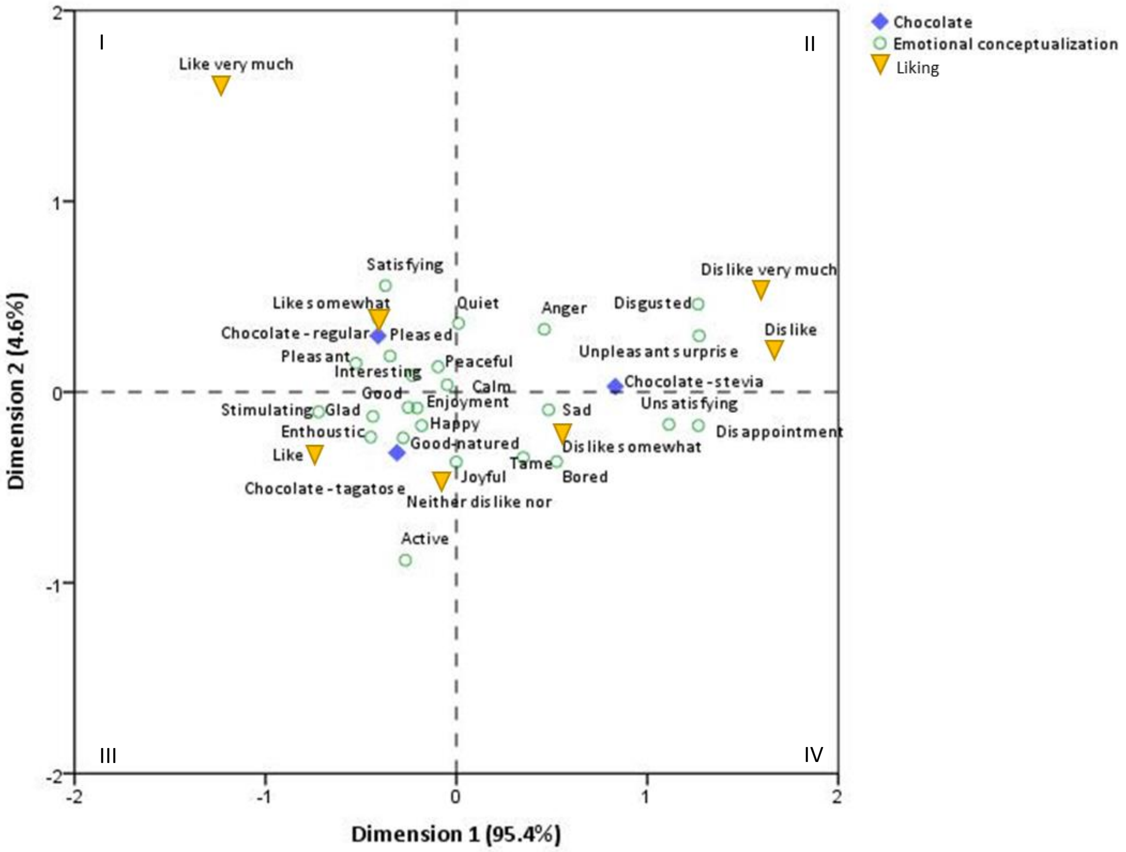

Figure 3. 2 Graphical presentation of correspondence analysis of the emotional conceptualizations together with the three different chocolate samples

Four quadrants (I-IV) are distinguished, based on two dimensions of semantic space (Arousal, Valence), as proposed by Spinelli *et al.* (2014) (I: valence positive, arousal low; II: valence negative, arousal high; III: valence positive, arousal high; IV: valence negative; arousal low). The filled labels represent the three different types of chocolate, the unfilled labels represent emotional conceptualizations, 'X' refers to overall liking score.

Consumers' emotional eating behavior, health and taste attitudes related to acceptance and emotional conceptualizations

The internal reliability of each factor of the health and taste attitudes questionnaire (HTAS) and for emotional eating of the Dutch eating behavior questionnaire (DEBQ-e) was calculated by use of Cronbach's alpha. The Cronbach's alpha for the factors has a good reliability on the health scale (General health interest 0.831; Light product interest 0.784; Natural product interest 0.76), an acceptable reliability on the taste scale (Consuming food for pleasure 0.621; Using food as reward 0.721; Craving for sweet foods 0.762), and a very high reliability on the emotional eating scale (0.907). Table 3.6 gives an overview of the means and standard deviations (SD) for the health and taste attitudes and emotional eating. Participants considered 'Pleasure' as the most important attitude, as they have scored this the highest on the health and taste attitudes questionnaire, followed by 'General health interest' and 'Using food as a reward'.

Table 3. 6 Means and standard deviations (SD) for health and taste attitudes and emotional eating (n=219)

Questionnaire	Factors	Mean	SD
Health and taste attitudes	Pleasure	5.06	0.81
	General health interest	4.42	0.92
	Using food as reward	4.12	1.10
	Craving for sweet foods	3.92	1.07
	Interest in natural products	3.72	0.99
	Interest in light products	3.34	0.95
Eating Behavior	Emotional eating	2.49	0.69

Items about health and taste attributes were measured by the validated questionnaire Health and Taste Attitude Scale (HTAS), attitudes were rated on 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Items about emotional eating behavior were measured by the validated emotional eating scale of the Dutch Eating Behavior Questionnaire (DEBQ-e) on a 5-point scale ranging from 1 (never) to 5 (very often).

To understand the role of sensory evaluation and emotional conceptualizations when comparing the chocolates, differences according to socio-demographics, eating behavior and attitudes were analyzed (Table 3.7). For age, for example, overall liking of chocolate with stevia differed significantly from the other chocolate types for every age category. Thereby, the overall liking of participants older than 46 years was significantly lower than for other age categories for chocolate with tagatose and chocolate with sugar. For BMI category, preference and emotional eating behavior, only non-significant differences were reported, similar as for health and taste attitudes (the latter not presented here).

Table 3. 7 Differences in mean liking by socio-demographics and eating behavior

	Overall liking							
	Regular		**Low-calorie sweeteners**					
	Chocolate + sugar		**Chocolate + tagatose**		**Chocolate + stevia**			
	Mean	SD	Mean	SD	Mean	SD	F-stat.	p-value
Socio-Demographic								
Age category								
18 - 25 years	4.85^{aA}	1.40	4.68^{aA}	1.33	3.02^{aB}	1.37	4.48*	0.002
26-45 years	4.59^{abA}	1.47	4.71^{aA}	1.19	3.02^{aB}	1.41		
46+ years	4.26^{bA}	1.54	3.82^{bAB}	1.49	3.38^{aB}	1.51		
BMI category								
Underweight (<18.5)	4.53	1.59	4.24	1.39	2.88	1.50	1.59	0.178
Normal weight (18.5-25)	4.71	1.45	4.68	1.34	3.12	1.39		
Overweight (> 25)	4.65	1.42	3.88	1.40	3.05	1.41		
Preference								
White	4.93	1.33	4.52	1.28	2.96	1.45	1.21	0.306
Milk	4.63	1.36	4.26	1.40	2.94	1.28		
Dark	4.64	1.62	4.76	1.36	3.35	1.53		
Eating behavior								
Emotional eating								
Low	4.65	1.73	3.76	1.60	2.22	1.78	0.99	0.412
Moderate	4.70	1.33	4.46	1.37	3.05	1.33		
High	4.67	1.59	4.68	1.39	3.24	1.44		

Note: Mixed factorial ANOVA with Bonferroni Post Hoc between age categories and chocolates. Mean liking with different letters (^{ab}) in same column and mean liking with different letters (^{AB}) in same row are significantly different (p≤0.05). Only significant differences in both rows and columns are presented. * significance p<.05.

The spider plots of Figure 3.3a-c represent the proportioned frequency for the three groups of participants when characterized as being low, moderate or high emotional eaters according to the DEBQ-e for the three different chocolates. The spider plots for the chocolate with sugar (Fig. 3.3a) and for the chocolate with tagatose (Fig. 3.3b) are similar and differ from the spider plot for chocolate with stevia (Fig. 3.3c). For chocolate with sugar (Fig. 3.3a), there was a significant difference between the three groups of emotional eaters for the emotional terms: 'stimulating' and 'anger'. For chocolate with tagatose (Fig. 3.3b) the emotional terms 'pleasant', 'glad' and 'enthusiastic' were checked more by the high emotional eaters. The emotional term 'sad' discriminated between the three groups for chocolate with stevia (Fig. 3.3c). In average the high emotional eaters selected a larger amount of emotional terms than the other emotional eaters (low and moderate) across all chocolates.

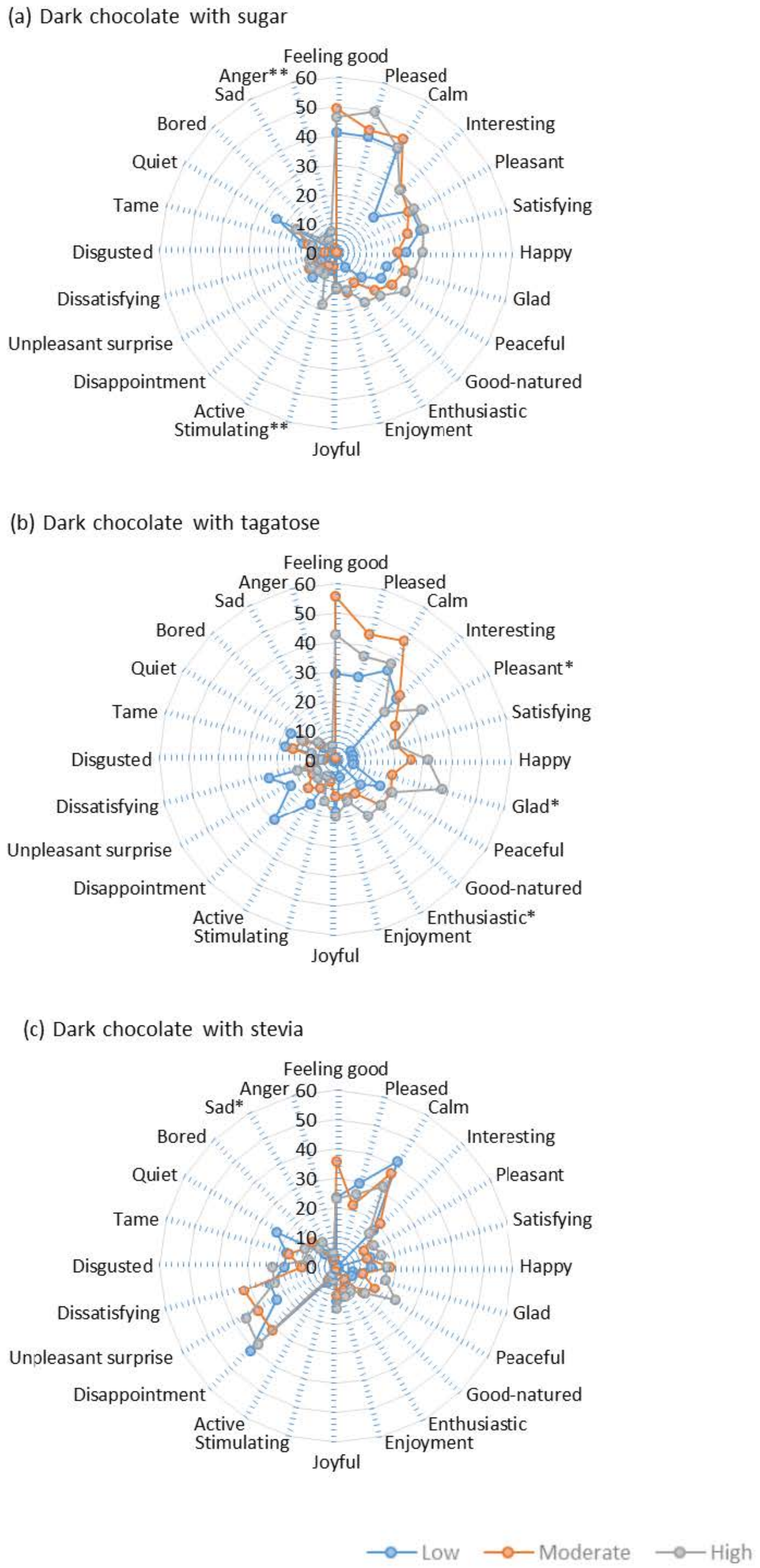

Figure 3. 3 Frequency of emotional conceptualizations segmented according to emotional eating behavior measured with DEBQ-e (in %)
Emotional terms with * are significantly different among the three groups at significant level of * 0.05 and **0.01. (a) chocolate with sugar, (b) chocolate with tagatose, (c) chocolate with stevia.

3.4 Discussion

This study examined consumers' sensory evaluation as well as emotional conceptualizations upon consumption of three types of dark chocolate: one with sugar and two with low-calorie sweeteners: tagatose and stevia. Three comparisons have been made: (1) a comparison of the two low-calorie sweeteners in chocolate in relation to sugar in chocolate on overall liking and sensory attributes, (2) a comparison of emotional conceptualizations associated with the chocolates and (3) a comparison of consumers' emotional eating behavior and health and taste attitudes in relation to acceptance and emotional conceptualizations.

Regarding the first comparison, (1) the overall liking and sensory attributes of the three types of chocolate, the results showed a significantly lower overall liking for chocolate with stevia as low-calorie sweetener compared to chocolate with sugar or with the other low-calorie sweetener, tagatose. Several studies have found similar lower levels of liking and acceptance for stevia products, such as mango nectar, grape nectar and chocolate compared to sugar products (Cadena et al., 2013; de Melo et al., 2009; Shah et al., 2010; Voorpostel et al., 2014). Overall liking of chocolate did not differ significantly between chocolate with sugar and chocolate with tagatose. These results are in line with a study that shows tagatose to have comparable physical attributes to sugar when the sugar is not completely substituted, as is the case in the chocolate with tagatose of this study (0.3 gram sugar remained in 100 gram) (Taylor, Fasina, & Bell, 2008).

The results showed a significant difference between the two low-calorie sweeteners for four of the five sensory attributes investigated in this study: texture, sweet flavor, bitter flavor and duration of aftertaste. The study did not find a significant difference for intensity of aftertaste. For texture, there was only a significant difference between the two low-calorie sweeteners and not between the low-calorie sweeteners and sugar. Stevia has been shown to retain hardness of chocolate under specific circumstances. Research of Shah *et al.* (2010) showed no substantial effect on hardness of chocolate when sucrose was replaced by stevia as sweetening agent only when inulin and polydextrose are used as bulking agents and only in chocolates without inulin HPX. For sweet flavor, both low-calorie sweeteners significantly differed from chocolate with sugar but chocolate with tagatose was significantly perceived as sweeter than chocolate with stevia. Just like in de Melo *et al.* (2009) chocolate with sugar is the sweetest, followed by chocolate with tagatose and chocolate with stevia is the least sweet. For bitter flavor, the use of stevia resulted in a more pronounced bitterness than tagatose which was similar to sugar. This corresponds with previous research showing an enhancing effect of stevia on non-sweet off flavors such as bitterness (Prakash et al., 2008) and a weakening effect of sucrose on bitterness (Prawira & Barringer, 2009). For duration of aftertaste, the results of this study support the longer aftertaste for chocolate with stevia (de Melo et al., 2009). Yet, for intensity of aftertaste, like the previous study of de Melo *et al.*(2009), there was no significant difference in intensity of aftertaste between tagatose and stevia, nor between the two low-calorie sweeteners and sugar.

When concluding on the comparison of the sensory attributes, the low-calorie sweetener tagatose in chocolate is perceived as more similar to sugar than the low-calorie sweetener stevia. This conclusion confirms previous research (Li et al., 2015; Livesey & Brown, 1996; Shankar, Ahuja, & Sriram, 2013). Chocolate with stevia differed from chocolate with sugar on overall liking, sweetness, bitterness and duration of aftertaste. Chocolate with tagatose is similar to chocolate with sugar on overall liking, texture, bitterness, duration of aftertaste and intensity of aftertaste. Although both are significantly different on sweetness, chocolate with tagatose was closer to chocolate with sugar on sweetness than chocolate with stevia.

Regarding the second comparison of the study, (2) the emotional conceptualizations consumers associate with the types of chocolates, the results showed significant differences between chocolate with tagatose and chocolate with stevia. Chocolate with tagatose was significantly more associated with positive emotional conceptualizations like the results of chocolate with sugar. Chocolate with stevia on the other hand aroused mostly negative emotions.

Although the emotional conceptualizations are quite similar, two differences between chocolate with tagatose and chocolate with sugar are worth mentioning. First, the semantic space as proposed by Spinelli *et al.* (2014) gives added information on consumer's perceptions of chocolate with sugar and chocolate with tagatose. By mapping the results in the semantic space, sugar and tagatose appeared to be slightly different on the activation dimension (low-high arousal). Second, on the positive emotional term 'satisfying', chocolate with tagatose showed a significant difference with chocolate with sugar. Yet, chocolate with tagatose was still significantly more associated with the term 'satisfying' than chocolate with stevia.

Whereas other research only showed comparable physical attributes and sweetness of sugar and tagatose (Livesey & Brown, 1996; Shankar et al., 2013), comparable to the first comparison in this study, the second comparison indicates that sugar and tagatose also elicit comparable (positive) emotional conceptualizations. Other recent studies have stressed the added and unique information of emotional responses to food, which can give new information for product development (Cardello et al., 2012; Gutjar et al., 2015; King & Meiselman, 2010; Thomson et al., 2010).

The third comparison (3) examines how consumers' emotional behavior and health and taste attitudes are related to acceptance and emotional conceptualizations. Chocolate consumers were profiled based on socio-demographics, consumer behavior, eating behavior and attitudes.

For acceptance, the study showed that mean overall liking for the chocolate with tagatose was lower for the participants older than 46 years. Sensory perception declines with age and stronger flavors are increasingly preferred (de Graaf, van Staveren, & Burema, 1996; Jos Mojet, Christ-Hazelhof, & Heidema, 2005; Murphy & Withee, 1986; Schiffman & Warwick, 1993).

For emotional conceptualizations, the emotional profile was linked to the consumption of the chocolates and the emotional eating behavior of the participants. The results showed that the group of high emotional eaters selected a larger amount of emotional terms on average than the low and moderate emotional eaters across all chocolates. This result is in line with previous research of Piqueras-Fiszman and Jaeger (2014) who have shown higher frequency of emotional words checked by high emotional eaters for chocolate brownie. The result is also in line with Jaeger and Hedderley (2013) who showed the intensity of emotion varied among individual emotional traits. These results hint at implementing emotional profiles for participants to avoid overrepresentation of high emotional eaters.

A first limitation of this study is that the study used only blind sensory evaluation of the chocolates. As a result the participants had no knowledge about the composition of the chocolates and had consequently no idea of the reduced amount of sugar in the chocolates. The study opted for blind evaluation to avoid bias. The altered composition of the chocolates could affect the expectations and consequently the evaluation of the types of chocolate. Torres-Moreno, Tarrega, Torrescasana & Blanch (2012) confirmed that consumers had a significantly higher liking for a premium brand chocolate compared to a standard brand in informed testing. However, in blind testing there was no difference in the consumers liking of both chocolates. Varela, Ares, Giménez & Gámbaro (2010) showed an influence of previous experiences, information on the label, the appearance and package on the sensory and hedonic expectations. Nutritional information also drives sensory evaluation into direction of expectations (Schouteten et al., 2015; Tuorila, 2015). For example, the evaluation of fattiness of a chocolate bar with a reduced fat label was lower in comparison to blind testing (Kähkönen & Tuorila, 1999) although overall evaluation did not to seem to differ (Norton, Fryer, & Parkinson, 2013). As this study focused on low-calorie sweeteners to reduce sugar, knowledge about the reduced amount of sugar could in the same way affect the consumers' perception.

A second limitation refers to the self-reported and explicit measurement of emotional conceptualizations, by asking participants to check the applicable emotion. This method relies on participants consciously and explicitly stating their experienced emotions. Although, this is a commonly used method in food-elicited emotion research, emphasis is often put on what the product is communicating to the consumer instead of what the product is really doing to them (Thomson et al., 2010). Future research should also focus on the non-self-reported and implicit measurement of emotions by tracking psychophysiological responses, such as facial expressions, skin conductance or brain activity (Köster & Mojet, 2015). Facial expression analysis, for instance, may contribute to detecting rapid, uncontrollable emotional responses that influence liking and preference of products but that cannot be consciously stated by participants. Both ways of measurements can also be combined. One study combining explicit (conjoint analysis) and implicit (facial expression) measurements found that some designs of packages generated happiness more than other designs (Pentus et al., 2014). Other studies found different results between explicit and implicit measurements. A recent study on sweeteners in black tea found a differentiation between liked versus disliked sweeteners when using verbal responses, but no differentiation when analyzing facial responses (Leitch et al., 2015; Mojet et al., 2015). Although implicit measurements merit attention, this study relied on explicit measurements as a commonly used method in food-elicited emotion research.

The preference and consumption of milk chocolate in, respectively, 58% and 49% of the participants is a third limitation of this study. The dominance of those preferring milk chocolate over dark chocolate could be a confounding factor. Nevertheless, to be selected, participants were asked whether they consumed all three types of chocolate (white, milk and dark). Before the study started they were informed that the study would be on dark chocolate. Furthermore, the focus of the study was on the sweeteners used in chocolate, rather than comparing dark versus other chocolates. As a consequence, participants who dislike dark chocolate were excluded, by which one can assume that the effect of those preferring milk chocolate on the evaluation of dark chocolate is negligible. The results also showed no significant effect of preference or consumption on overall liking of the chocolates (Table 3.7).

3.5 Conclusion

This study looked at two low-calorie sweeteners, tagatose and stevia, to reduce sugar in dark chocolate by making three comparisons. When comparing overall liking and sensory attributes, the low-calorie sweetener tagatose in chocolate is perceived as more similar to sugar than the low-calorie sweetener stevia. The second comparison indicates that sugar and tagatose also elicit comparable (positive) emotional conceptualizations. The third comparison showed different liking of tagatose in different age groups with a lower liking for participants older than 46 years. To reduce sugar intake without changing the sensory perception nor the emotional conceptualization, tagatose seems to be a promising low-calorie sweetener for dark chocolate as this study showed it does not differ significantly from sugar in overall liking, most sensory attributes and emotional conceptualization. Moreover, this study contributes to a better understanding of food experience of low-calorie sweeteners in chocolate through both sensory and emotion research which can provide new ways to reduce sugar intakes and to brand and improve low-calorie sweeteners.

3.6 References

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Chapter 4
Consumers' emotional conceptualizations elicited by tasting dark chocolate using a non-verbal emoji-based questionnaire

This chapter is based on:

Lagast, S., Schouteten, J.J., Gellynck, X., De Steur, H. (2017). Consumers' emotional conceptualizations elicited by tasting dark chocolate using a non-verbal emoji-based questionnaire. Under review in *Appetite*. IF: 3.403; R=8/51 (Q1; Behavioral Science).

Abstract

Increasing attention to emotion in consumer and sensory research has led to the development of many instruments to capture consumers' emotions elicited by food. While various emotional lexicons have been developed, there is growing concern about the translation problem of such verbal measurements. This has led to the recent introduction of non-verbal emoji-based questionnaires. This study explored the applicability of using emoji within a single product category, dark chocolate. In total, 146 adult participants (mean age: 25.5 ± 5.4) participated in the study. Significant differences among the chocolate samples were found in five out of 33 emoji: *smiling face with smiling eyes* 😊, *grinning face* 😀, *face with stuck out tongue and winking eye* 😜, *expressionless face* 😑 and *confused face* 😕. As expected, positive emoji were more used for the higher liked samples. Two emoji (*face with stuck out tongue and winking eye* 😜 and *expressionless face* 😑) were able to discriminate between four equally liked samples. The *expressionless face* emoji 😑 was able to discriminate between all five chocolate samples and was significantly more used for one sample. Baseline mood influenced the emotional evaluation, positive emoji were associated with a positive baseline mood and negative emoji were associated with negative baseline mood. This study provides support for the application of emoji as a non-verbal measurement of food-elicited emotion and shows that they can discriminate between products within the same product category.

Research question 3: To what extent do emoji as a non-verbal explicit measure contribute to the measurement of food product-elicited emotion?

RQ3a *In what manner do the explicit non-verbal emotional conceptualizations discriminate between different dark chocolates?*

RQ3b *What influence has baseline mood on the non-verbal emotional conceptualizations?*

4.1 Introduction

Measuring emotional conceptualizations associated with food products has gathered momentum in the field of sensory and consumer research (Köster & Mojet, 2015) in order to capture more information about consumers attitudes towards food products (Jiang et al., 2014; Meiselman, 2015; Thomson, 2007). Several research papers illustrated that that consumers' emotional associations with food products can add this information beyond overall acceptance (Cardello, et al., 2012; Gutjar, et al., 2015b; King & Meiselman, 2010; Ng, Chaya, & Hort, 2013; Schouteten, et al., 2015a; Spinelli, Masi, Dinnella, Zoboli, & Monteleone, 2014; Thomson, Crocker, & Marketo, 2010), and even significantly improve food choice prediction (Dalenberg, et al., 2014; Gutjar, et al., 2015a).

This increased attention has led to the development of many instruments to capture consumers' emotions elicited by food (Dalenberg, et al., 2014). Depending on how emotional associations are assessed, two types of measures can be distinguished: (i) explicit measures and (ii) implicit measures. Explicit measures reflect self-reported responses about participants' feeling or emotions upon consumption. Implicit measures, on the other hand, refer to not self-reported responses and register emotions continuously, without the need of (or with limited) cognitive resources (Danner, Haindl, Joechl, & Duerrschmid, 2014; De Houwer & Moors, 2007; Mojet, et al., 2015). Whereas this measures is less intervening, explicit measures are quick in use and user-friendly (Danner, et al., 2014; Köster & Mojet, 2015).

To date, explicit measures are mostly applied to measure emotional associations, most likely due to the lower cost and technical easiness (Danner, et al., 2016). Explicit measures can be divided into verbal or non-verbal measurements. The former uses a questionnaire format with a list of emotional terms or a set of emotional descriptors or sentences, which is known as an emotional lexicon. An emotional lexicon can be checked (e.g. Check-all-that-apply, CATA) or rated (e.g. RATA or 5-point rating scale). The most commonly used verbal self-reported measurement is the standard emotional lexicon, known as the EsSense Profile™ (King & Meiselman, 2010). However, the application of consumer-led product-specific emotion lexicons (Ng, et al., 2013; Schouteten, et al., 2015b; Spinelli, et al., 2014; Thomson, et al., 2010) is on the rise. Previous research has also shown that the consumers' general mood before tasting had an influence on the evaluation of product-elicited emotion (Danner, et al., 2016). Danner, et al. (2016) found that emotional conceptualizations with positive valence were positively correlated with moods of positive valence and found similar results for emotional conceptualizations and moods with negative valence. Unfortunately, the inclusion of a baseline measurement of mood is not common in sensory research

Verbal self-reported measurements have several limitations. A well-known difficulty is the translation problem. When translating emotional terms there is a loss of meaning, which makes it hard to apply them in a multicultural setting, on top of the known impact of cultural differences in emotional perceptions and experiences (van Zyl & Meiselman, 2016). Another problem is that some emotional terms are easily accessible for consumers, while others are not. Consumers tend to replace those terms by rather irrelevant rational associations (Thomson & Crocker, 2013). Furthermore, as reported by Jaeger, Cardello, and Schutz (2013), some consumers might consider using certain words to describe how they feel rather strange. Non-verbal measurements can circumvent these problems, as translation is not needed (Mojet, et al., 2015). Such measurements use images to depict different emotions rather than emotional terms. Several instruments have been developed, one of the most known and applied measurements in food research is the Product Emotion Measurement Instrument (PrEmo) (Desmet, 2003). PrEmo uses different cartoons that are expressing different emotions. This tool has been implemented to examine consumers' emotions for several food products such as breakfast drinks (Dalenberg, et al., 2014) and ginger bread (den Uijl, Jager, Zandstra, de Graaf, & Kremer, 2016).

Emoji can also offer an intuitive and informal way to express emotions (Walther & D'Addario, 2001) and attitudes (Dresner & Herring, 2010). Emoji are an novel version of emoticons, i.e. puntuations-based presentations of facial expersions, objects and symbols, e.g. ":-)" , that are presented in a pictoral form, e.g. through the Apple Color Emoji fontset, such as 😊) (Marengo, Giannotta, & Settanni, 2017). They can be seen as simplifications of facial expersions or body gestures and are widespread in use (Marengo, 2017). Emoji are used by 92% of the online population, of which women and young adults under 30 are most frequent users (EMOGI, 2016). Emoji are functional similar to words and serve as a alternative of non-verbal cues in computer mediated communication (Derks, Fischer, & Bos, 2008; Jibril & Abdullah, 2013; Walther & D'Addario, 2001).

In a food context, Vidal, Ares and Jaeger (2016) found that emoji were spontaneously used to express emotional reactions in eating situations (21% of tweets related to eating situations included emoji). Recently, Jaeger, Vidal, Kam, and Ares (2017b) applied emoji as measure for emotional associations in a food context. They found that emoji can be used to discriminate emotional associations between food names. In comparison with PrEmo, emoji have the advantage that they are more familiar to consumers and have more potential to be used in a cross-cultural context (Jaeger, et al., 2017b).

Jaeger et al. (2017a) were the first to assess emotional associations during consumption of food and beverages by use of emoji. Consumers evaluated a wide range of food and beverages by use of check-all-that-apply (CATA) response format to assess product-elicited emotions. Their reseach confirmed the relevance of using an emoji-based questionnaire to assess emotional associations to tasted food and beverages in two consumer groups.

This study contributes to the present research by examining the application of an emoji-based questionnaire for assessing product-elicited emotions from one single product category, dark chocolate. As dark chocolates with two low-calorie have been shown to elicit different emotional conceptualization profiles by use of a verbal emotional lexicon in comparison with dark chocolate with sugar (Lagast, De Steur, Schouteten, & Gellynck, 2017), this study examines the non-verbal emotional conceptualization profile of different dark chocolates. Additionally, this research looked to the influence of baseline mood on the evaluation of food product-elicited emotions and has also taken the sensory profile of the products into account.

4.2 Materials and methods

Participants

Participants were recruited from a database of volunteers for sensory tests. To be eligible for participation, potential participants were not allowed to have allergies nor food intolerances (lactose, milk, nuts or gluten), needed to consume dark chocolate and had to be users of emoji during communication (e.g. text messaging, social media,…).

In total, 146 participants (mean age = 25.5, S.D. = 5.4) completed the questionnaire, of which 80 females and 66 males. Participants were unaware of the aim of the study, but were informed they would have to taste dark chocolates. All participants used Internet daily. A small number of the participants (6.2%) only owned one electronic device (desktop computer, laptop computer, tablet/IPad and/or smartphone), while all other participants owned at least two. Most participants indicated to use emoji either sometimes (52.7 %) or always (41.8 %) when sending or posting a message. Only a small part of the consumer sample (5.5%) reported to use them rarely.

Samples

This study used dark chocolate as a case. Chocolate has a hedonic appeal due to its composition and sensory attributes (fat, sugar, texture and aroma) (Bruinsma & Taren, 1999) and is therefore often used in scientific research on consumers' emotions (Dorado, Perez-Hugalde, Picard, & Chaya, 2016; Jaeger, et al., 2013; Lagast, et al., 2017; Piqueras-Fiszman & Jaeger, 2014b; Radin, Hayssen, & Walsh, 2007; Schouteten, et al., 2015b; Spinelli, et al., 2014; Spinelli, Masi, Zoboli, Prescott, & Monteleone, 2015; Thomson, et al., 2010).

Five dark chocolates, representative for a variety within dark chocolates were chosen: two regular dark chocolates (A-label and private label), two dark chocolates (A-label) with low-calorie sweeteners (tagatose and stevia), and one dark chocolate (private label) with bio-label. All chocolates were available at the supermarket (Table 4.1). No label information, nor information on sweeteners was given to the participants. Appendix C gives a detailed description of the five dark chocolates.

Table 4. 1 Chocolate samples used in the study

Sample	Description
S1	Dark chocolate private label
S2	Dark chocolate private label with bio-label
S3	Dark chocolate A-label
S4	Dark chocolate A-label with sweetener tagatose
S5	Dark chocolate A-label with sweetener stevia

Samples were served at room temperature in a transparent plastic container marked with a 3-digit code and no brand information was visible on the chocolate samples. Serving sizes were equal in size and sufficient to allow 3 bites per sample. Samples were presented monadically and in accordance with experimental designs that were balanced for order and carry-over effects.

Experimental procedure

Sensory tests took place in the sensory facilities of the university. Participants evaluated the samples individually in a sensory booth under controlled circumstances, such as light and climate control. The sensory software package Eyequestion v.4.1.7 (Logic 8, The Netherlands) was used for data collection. The flow of the screening and questionnaire is depicted in Figure 4.1.

Before starting the questionnaire, participants needed to complete three screening questions in order to assess their eligibility for the study (food allergies, consumption of dark chocolates, use of emoji in communication).

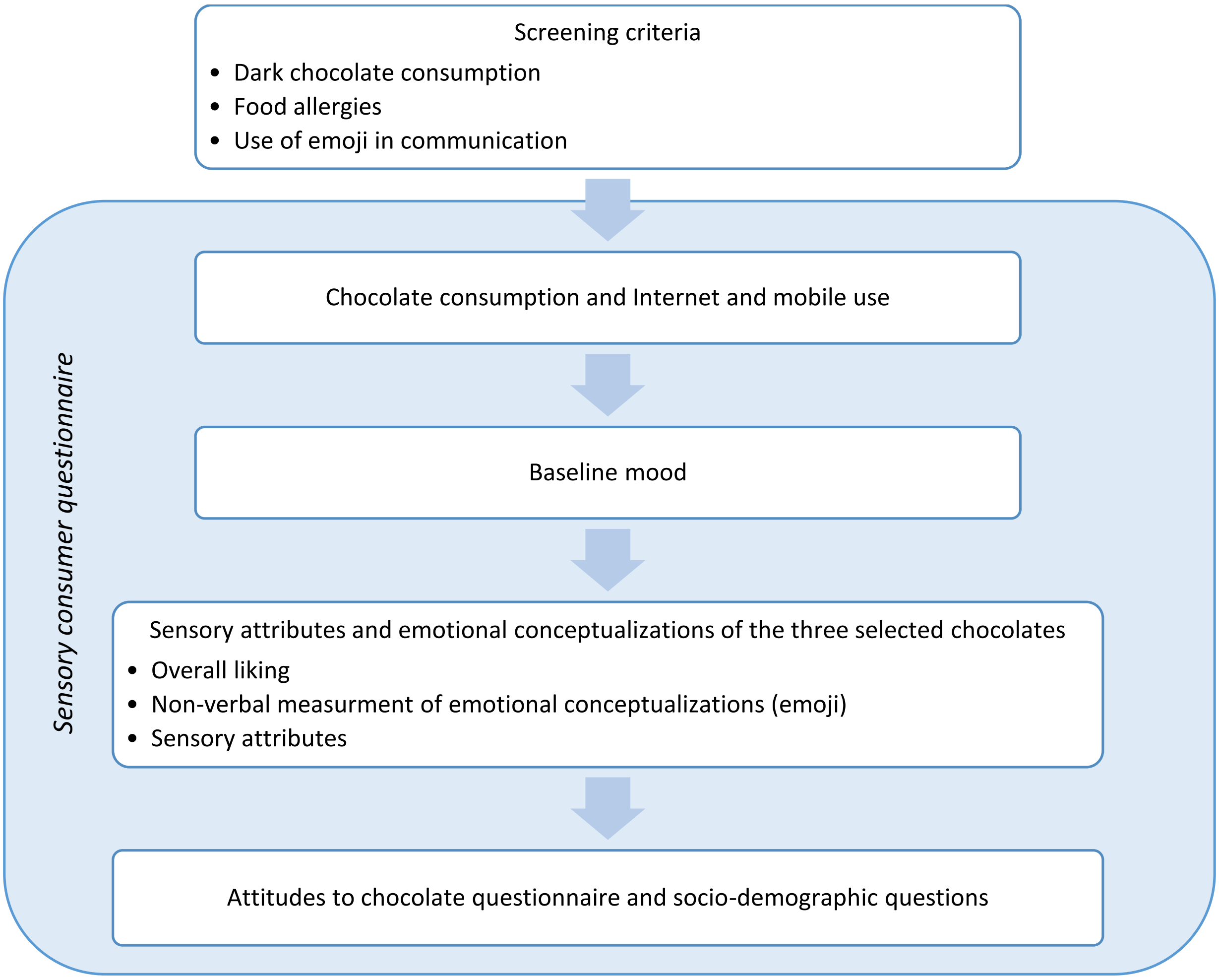

Figure 4. 1 Screening and questionnaire flow

First, the questionnaire started with questions about chocolate consumption (preference, frequency of consumption). Questions regarding Internet and mobile use (frequency of Internet use, number of electronic devices, frequency of emoji use) were based on Jaeger, et al. (2017b).

Second, the baseline mood of the participants was examined by a list of 33 emoji (Table 4.2). This list has been applied in previous research by Jaeger, et al. (2017b). Given the length of the list and the lack of guidance for selecting emoji for sensory research, an extensive selection of emoji was deemed beyond the scope of the present paper. Thereby, participants were also able to indicate that none of the emoji were applicable. The Apple version of the emoji (Emojipedia, 2016) was applied in this study, using 1.5 × 1.5 cm images to ensure they were clearly visible. Participants were instructed to rate all applicable emoji which described how they felt using a 4-point rate-all-that-apply (RATA, 1 = slightly, 2 = moderately, 3 = very, 4 = extremely) scale.

Third, participants received five pieces of dark chocolate at the same time, one of each type of chocolate. In a randomized order, participants evaluated one piece of dark chocolate at a time. Participants were instructed to take a first bite of the chocolate and to rate the overall liking using a 9-point bipolar scale (ranging from 1 = extremely dislike to 7 = extremely like). Afterwards they had to complete the sensory and emotional conceptualization profiling of each sample. Regarding the sensory profiling, 21 attributes were selected based upon prior research covering multiple sensory modalities (appearance, aroma, flavor, texture, aftertaste, mouth feel) (Table 4.2). The sensory attributes were randomized among the samples and a 5-point RATA scale (1 = not at all, 2 = slightly, 3 = moderately, 4 = very, 5 = extremely) was used for the sensory profiling.

Table 4. 2 List of the emoji and sensory attributes used in the study

Emotional conceptualization profiling			
Emoji	Description	Emoji	Description
😊	Smiling face with smiling eyes	😴	Sleeping face
😀	Grinning face	😳	Flushed face
😄	Smiling face with smiling eyes and open mouth	😝	Face with stuck out tongue and tightly closed eyes
😍	Smiling face with heart shaped eyes	😱	Face screaming in fear
☺️	Smiling face	😕	Confused face
😌	Relieved face	😖	Confounded face
😎	Smiling face with sunglasses	😒	Unamused face
😏	Smirking face	😫	Tired face
😛	Face with stuck out tongue	😔	Pensive face
😁	Grinning face with smiling eyes	😣	Persevering face
😉	Winking face	😩	Weary face
😘	Face throwing kiss	😞	Disappointed face
😜	Face with stuck out tongue and winking eye	😠	Angry face
😂	Face with tears of joy	😓	Face with cold sweat
😐	Neutral face	😢	Crying face
😑	Expressionless face	😭	Loudly crying face
😬	Grimacing face		

Sensory profiling			
Sensory attributes			
brown color	bitter	cocoa aroma	sticky
firm	salty	grainy	rough
melting	creamy	buttery flavor	aftertaste
bright	cocoa flavor	chocolate aroma	off-flavor
sweet	chocolate flavor	thick	smooth
sour			

For the emotional conceptualization profiling, the same 33 emoji were used as when participants assessed their mood before tasting the samples (baseline assessment; Table 4.2). For each sample, participants were instructed to take another bite and to select the appropriate emoji at that moment. The option to select "none of the emoji apply" appeared if participants selected none of the emoji. A 4-point RATA scale (1 = slightly, 2 = moderately, 3 = very, 4 = extremely) was used for the emoji. The presentation order of the emoji was randomized among the samples.

Regarding the assessment of the baseline mood and the emotional conceptualization profiling task, it should be noted that participants were not informed about the difference between mood and emotions as this would probably confuse the participants and leading to biased results. This strategy is conform with the study of Danner, et al., 2016.

Next, participants had to indicate how good each statement of the Attitudes to Chocolate Questionnaire matched their own feelings on a 100 mm line that uses “not at all’ and “very much like me” as anchors (Benton, Greenfield, & Morgan, 1998). Lastly, participants were asked to answer socio-demographic questions regarding their age, gender, height, weight and education.

Data analysis

Standard procedures for the statistical analysis of RATA questions were applied (Ares & Jaeger, 2017; Meyners, Jaeger, & Ares, 2016). Overall liking scores were analyzed using a mixed model ANOVA considering sample as fixed effect and consumer as random effect. Tukey's test was used for post-hoc comparison of means. Frequency of use of emoji was calculated for each sample by counting the number of participants who selected the emoji for each stimulus. Significant differences among stimuli considering the frequency of selection of each emoji were evaluated using Cochran’s Q test. When considering the intensity, not selected values were recoded to zero as suggested by Meyners, et al. (2016). ANOVA was performed considering sample and consumer as fixed effects to determine significant differences between the samples for each sensory term and emoji (Meyners, et al., 2016).

Correspondence analysis (CA) was performed on the frequency table of the emoji frequency scores considering chi-square distance in order to obtain a bi-dimensional representation of samples and emoji. Similarity between the sample and term configurations in the first two dimensions of the CA was evaluated using the RV coefficient (Robert & Escoufier, 1976).

The factors craving (Cronbach’s alpha = 0.862), guilt (Cronbach’s alpha = 0.865) and functional (Cronbach’s alpha = 0.405) were created by calculating the mean value of each related item of the ACQ (Benton, et al., 1998). A Pearson correlation was carried out to examine the interaction between each of these attitudes and the emotional conceptualization when consuming a sample of dark chocolate.

To examine the relationship between mood, product-elicited emotions and overall liking, Pearson correlation coefficients were calculated using the participant’s mean values of each emoji and liking score for the samples (Danner, et al., 2016).

4.3 Results

Overall liking and sensory profiling

Overall liking of the chocolate with stevia was significantly lower than the other samples. The average scores for the intensity of the sensory attributes of the chocolate samples evaluated by the consumers is shown in Table 4.3. Significant differences ($p < 0.05$) among samples were found for sensory attributes (Table 4.3), illustrating that the evaluated samples had different sensory profiles.

Table 4. 3 Mean overall liking scores (1-9 hedonic scale) and mean scores for the sensory attributes (5-point RATA scale, not applicable is treated as 0) of the five chocolate samples

Dark chocolate	**Private label**	**Private label + Bio-label**	**A-label**	**A-label + Tagatose**	**A-label + Stevia**
Overall liking	6.00^{a}	5.79^{a}	5.95^{a}	5.97^{a}	5.09^{b}
Aftertaste	1.47	1.67	1.45	1.40	1.57
Bitter	0.73^{a}	0.78^{ab}	1.03^{a}	0.97^{a}	0.52^{b}
Brown color	1.68^{ab}	1.95^{a}	1.98^{a}	1.38^{b}	0.52^{c}
Chocolate aroma	1.18^{b}	0.79^{b}	0.95^{b}	1.16^{b}	2.3^{a}
Chocolate flavor	0.56	0.51	0.79	0.91	0.51
Creamy	1.92^{a}	1.74^{a}	1.59^{ab}	1.64^{ab}	1.00^{b}
Firm	0.53^{a}	0.20^{b}	0.14^{b}	0.12^{b}	0.29^{ab}
Grainy	1.35	1.32	1.33	1.31	0.77
Melting	0.40	0.17	0.29	0.29	0.34
Bright	1.25	1.27	1.29	1.40	1.49
Sour	0.64	0.79	1.01	1.00	0.53
Sticky	1.40^{a}	0.95^{ab}	0.98^{ab}	0.79^{b}	1.02^{ab}
Smooth	0.27	0.26	0.26	0.30	0.26
Sweet	0.41^{ab}	0.38^{ab}	0.21^{b}	0.18^{b}	0.56^{a}
Salty	0.24	0.18	0.23	0.21	0.20
Cocoa flavor	1.40	1.21	1.41	1.27	1.38
Cocoa aroma	1.39^{a}	0.99^{ab}	0.99^{ab}	0.81^{b}	1.11^{ab}
Buttery flavor	0.58	0.61	0.63	0.75	0.77
Thick	0.62	0.53	0.30	0.39	0.51
Rough	0.41	0.38	0.21	0.25	0.42
Off-flavor	0.35^{b}	0.88^{a}	0.49^{ab}	0.58^{ab}	0.73^{ab}

note: ^{abc} denotes that values of overall liking / sensory attribute differed significantly between the samples ($p < 0.05$)

Baseline mood

Before receiving the chocolate samples, usage frequency of emoji varied from 1.4% to 50.7% (Table 4.4). Moreover, 1 person indicated that no emoji described how he or she felt before tasting the chocolate samples. The mean intensities of the emoji were all rather low and can be found in Table 4.4.

Table 4. 4 Frequency of use (in %) and mean intensities of the emoji before the evaluation of the chocolate samples

Emoji	**Usage frequency** (%)	**Mean intensity** (0-5)	**Emoji**	**Usage frequency (%)**	**Mean intensity** (0-5)
😊	50.7	1.46	😴	17.8	0.38
😀	39.7	1.14	😳	1.4	0.03
😄	25.3	0.76	😝	5.5	0.12
😍	17.8	0.53	😱	2.1	0.06
☺️	19.2	0.51	😕	5.5	0.13
😌	21.2	0.53	😖	2.1	0.04
😎	22.6	0.62	😒	4.1	0.11
😏	11.0	0.30	😫	2.1	0.05
😛	9.6	0.24	😔	4.1	0.08
😁	9.6	0.27	😣	2.7	0.06
😉	18.5	0.47	😩	2.1	0.05
😘	4.8	0.16	😞	3.4	0.04
😜	13.7	0.35	😠	1.4	0.02
😂	6.8	0.22	😓	1.4	0.03
😐	12.3	0.29	😢	3.4	0.10
😑	4.8	0.08	😭	1.4	0.03
😬	5.5	0.16			

Emoji responses during chocolate evaluation

Participants used on average 6% of the emoji or around 2 emoji to describe how they felt upon consuming a chocolate sample. The average values, based on an aggregate analysis of all samples, showed that only two out of 33 emoji had usage frequencies > 20%: *smiling face with smiling eyes* (😊) and *grinning face* (😀). These are both emoji related with positive feelings. In contrast, emoji which were less (<1%) associated with the chocolate samples, were mainly negative: *face screaming in fear* (😱), *tired face* (😫), *disappointed face* (😞), *angry face* (😠), *face with cold sweat* (😓) and *loudly crying face* (😭). Also the emoji *face with tears of joy* (😂) was less (>1%) associated with the chocolates.

The frequency of use of the 33 emoji for the five samples is shown in Fig. 4.2. It can be seen that significant differences among the chocolate samples were found for only five out of 33 emoji: *smiling eyes* (😊), *grinning face* (😀), *face with stuck out tongue and winking eye* (😜), *expressionless face* (😑) and *confused face* (😕). Positive emoji were more used for the higher liked samples (S1-S4) and also negative emoji had a lower usage frequency for these four samples. Although dark chocolate samples private label with and without bio-label, A-label with and without sweetener tagatose had similar liking scores, 2 emoji (*face with stuck out tongue and winking eye* (😜) and *expressionless face* (😑)) were able to discriminate between these four equally liked samples. The *expressionless face* emoji (😑) was able to discriminate between all five chocolate samples and was most used for the dark chocolate with sweetener stevia which was significantly lower liked then the other four samples. Also, 1% (for chocolate with A-label and private label) and 3% (for chocolate with sweetener stevia) of the respondents indicated that no emoji were applicable to describe how they felt when tasting a particular sample.

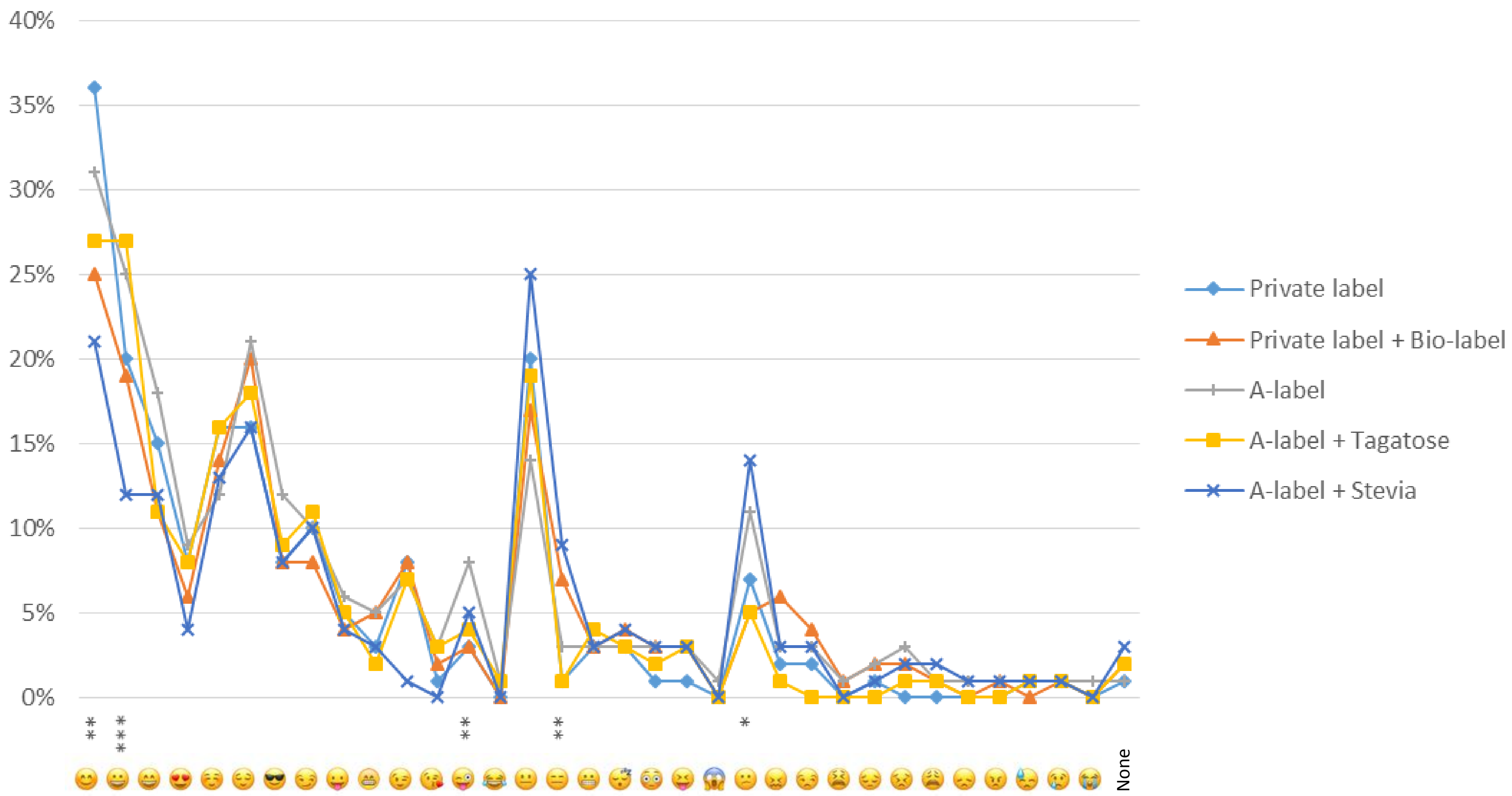

Figure 4. 2 Frequency of use of the 33 emoji for the evaluation of five dark chocolate samples (% of participants)
*, **, *** is used to denote that the frequency of use for an emoji differs significantly for respectively p < 0.05, <0.01 and p<0.001 between samples

When taking the intensities into account, only two emoji were able to discriminate between the five samples: *grinning face* (😀) and *expressionless face* (😑) (Table 4.5). Moreover, the mean intensities are rather low but this could be expected given the low number of emoji used by the participants. An overview of the mean intensities of the emoji for the different samples can be found in Table 4.5.

Table 4. 5 Mean intensities of the emoji for each sample (5-point rating scale, not applicable is treated as 0)

Emoji	**Private label**	**Private label + Bio-label**	**A-label**	**A-label + Tagatose**	**A-label + Stevia**
😊	1.43	1.07	1.30	1.21	0.89
😀	0.95[ab]	0.96[ab]	1.10[ab]	1.16[a]	0.58[b]
😄	0.79	0.61	0.91	0.62	0.59
😍	0.50	0.41	0.46	0.45	0.22
☺️	0.66	0.64	0.57	0.87	0.60
😌	0.74	0.93	0.92	0.76	0.67
😎	0.39	0.40	0.68	0.51	0.40
😏	0.45	0.37	0.47	0.54	0.47
😛	0.27	0.18	0.31	0.32	0.21
😁	0.18	0.31	0.34	0.15	0.15
😉	0.43	0.43	0.34	0.38	0.08
😘	0.11	0.14	0.22	0.19	0.00
😜	0.15	0.15	0.39	0.23	0.32
😂	0.00	0.00	0.03	0.08	0.00
😐	0.78	0.71	0.60	0.86	1.01
😑	0.10[b]	0.34[ab]	0.11[ab]	0.06[b]	0.44[a]
😬	0.19	0.15	0.18	0.22	0.19
😴	0.12	0.17	0.20	0.13	0.13
😳	0.06	0.16	0.11	0.13	0.18
😝	0.07	0.19	0.14	0.14	0.16
😱	0.00	0.00	0.01	0.00	0.00
😕	0.33	0.29	0.46	0.27	0.63
😖	0.14	0.37	0.11	0.07	0.20
😒	0.13	0.21	0.20	0.00	0.15
😫	0.00	0.04	0.01	0.00	0.00
😔	0.08	0.08	0.07	0.00	0.08
😣	0.00	0.11	0.09	0.08	0.10
😩	0.00	0.03	0.01	0.04	0.11
😞	0.00	0.00	0.04	0.00	0.06
😠	0.00	0.08	0.04	0.00	0.08
😓	0.03	0.00	0.01	0.04	0.04
😢	0.03	0.03	0.04	0.03	0.03
😭	0.00	0.00	0.01	0.00	0.00

note: [ab] denotes that values of mean intensity of the emoji differed significantly between the samples ($p < 0.05$)

Figure 4.3 shows the bi-plot of the first two dimensions from the CA performed on the frequency of emoji use. The first two dimensions explained 71.6% of the inertia. The first dimension explained almost half of the inertia and is linked to the valence of the emoji representing positive emoji on the left side and negative emoji on the right side. When considering the average overall liking scores, the two most liked samples (chocolate with private label, S1 and chocolate with A-label and tagatose, S4) also on the left and the least liked sample (chocolate with A-label and stevia, S5) is on the right. Emoji conveying love or smiling (e.g. 😍 and 😊) were primarily associated with chocolate with private label, S1 and chocolate with A-label and tagatose, S4 while emoji conveying a more neutral (e.g. 😐) or negative meaning (such as 😕) were more strongly associated with the less liked chocolate with stevia, S5.

The second dimension, explaining 23% of the inertia, differentiates according to the emotional arousal. Regarding to the place of the samples on the plot, the dark chocolate with private label and bio-label (S2) is situated together with high arousal emoji such as 😜 and the dark chocolate with A-label and stevia is linked to lower arousal emoji such as 😕. Despite the other samples related to positive valence dimension are situated in different quadrants on the plot the relation with emoji and the arousal dimension is not that clear.

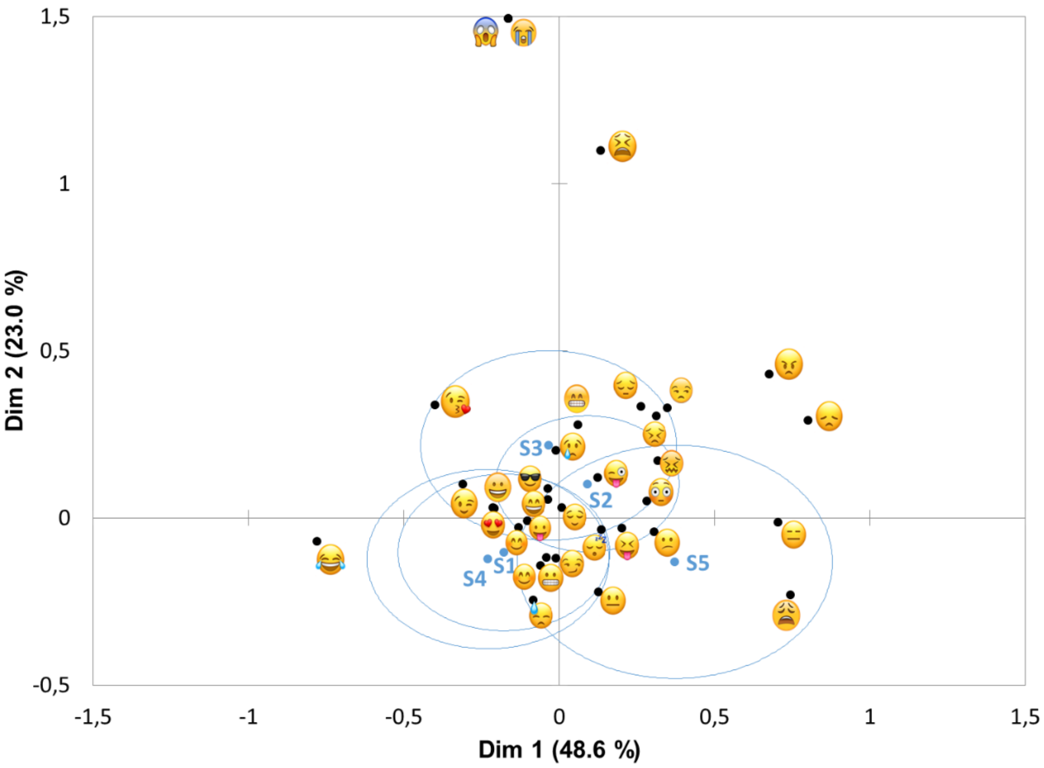

Figure 4. 3 Bi-plot of the two first dimensions following Correspondence Analysis on frequency table for use of each of the emoji for the five chocolate samples

Relationship between ACQ with overall liking and emotional conceptualizations of chocolate samples

Craving for chocolate was moderate (mean = 35.4, S.D.=18.9) for the overall sample but higher for female (mean = 40.9, SD = 18.3) than male (mean = 28.7, S.D. = 17.6) participants. The mean overall value for a functional approach for chocolate (mean = 32.4, SD = 15.8) was similar to the value of craving. Also, most participants are only to a small extent feeling guilty when normally consuming chocolate (mean = 23.5, S.D. = 17.2).

A positive correlation was found between the functional score and mean overall liking of the chocolate samples (r = 0.183, n = 146, p = 0.027). No correlation was found between the craving score (r = 0.138, n = 146, p = 0.096) or guilt score (r = - 0.044, n = 146, p = 0.601) with the mean overall liking score. The intensity of the *pensive face* (😔) was negatively correlated with the craving score (r = 0.116, n = 146, p = 0.05). The functional score was positively correlated with the intensity of applicability of the emoji *face* with stuck out tongue (😛; r = 0.195, n = 146, p = 0.018), *face screaming in fear* (😱; r = 0.170, n = 146, p = 0.04) and *loudly crying face* (😭; r = 0.170, n = 146, p = 0.04).

Relationship between mood, liking and emotional conceptualizations

The results of the correlation analyses between mood, liking and emotional conceptualizations are shown in Appendix D. Overall liking was positively associated with three positive emoji: *smiling face with smiling eyes and open mouth* (😄), *grinning face* with smiling eyes (😁) and *winking face* (😉). However, it should be noted that these significant correlations were rather small given they were only in the range between 0.163 – 0.190 (Cohen, 1977). Overall, emoji with positive association were associated with positive baseline mood and those with negative associations with negative baseline mood. Several significant correlations between the emoji and the baseline mood were found, such as the significant correlation between emoji 😱 and mood 😓 and between emoji 😭and mood 😓.

4.4 Discussion

The main aim of the present research was to investigate the potential of emoji as a non-verbal explicit measure to assess emotional associations to food-related stimuli of a single product category, dark chocolate. Secondly, the influence of baseline mood of the consumer on the emotional evaluation after consumption was examined.

On average, consumers selected 2 emoji (6%) to indicate how they felt when consuming a chocolate sample. In general, these selected emoji were related to positive feelings. When considering the frequency of use of the emoji, some emoji are able to discriminate between the chocolate samples. Overall, the frequency of use was lower compared to previous research reporting 11-19% (Jaeger, et al., 2017a). Several reasons could have led to a lower frequency of use and a rather low discriminative ability. Firstly, our study only included facial emoji, whereas others have included of non-facial emoji such as *thumbs up sign* (👍) which were heavily used by the participant. Secondly, the RATA response format compared to the CATA response format used by Jaeger, et al. (2017a) could influence the usage frequency of emoji in food contexts (Ares & Jaeger, 2017). Consumers' tend to use a low number of emoji upon consumption when using a RATA response format. Additionally, the use of RATA which requires a higher cognitive involvement and longer response time. Thirdly, a list of 33 emoji were used in this research. Although this number is comparable to the number used in verbal lists for emotional conceptualization profiling such as EsSense Profile™ (King & Meiselman, 2010), less number of emoji and a consumer-defined list of emoji might have yielded a higher usage frequency as suggested by Ng et al. (2013). Lastly, the list of emoji contained rather more emoji related to neutral and negative feelings. In verbal emotional lexicons is has been shown that more positive valence emotions are selected, known as the hedonic asymmetry (Desmet & Schifferstein, 2008), which can also explain the low frequency of use. In future research, one could opt for developing and testing a predefined consumer-list of emoji or including non-facial emoji, such as *thumbs up sign* (👍) although they express emotions less directly.

The low frequency of emoji use could also be the cause of the ability of consumers to assess or indicate their emotions upon consumption. One of the major limitations of explicit measures is that consumers are not always able to describe their feelings (Köster & Mojet, 2015). It has been suggested that the use of non-verbal emotional assessment is more intuitive than verbal emotional terms (Marengo, et al., 2017). But this contradicts with our rather low mean usage frequencies (6%) compared to studies using verbal terms, which often report term usage frequencies around 15 – 20% (Schouteten, et al., 2017). Future research is recommended using samples of the same food product category in order to compare the performance of emoji versus verbal questionnaires for conducting emotional conceptualization profiling with food products.

The Correspondence Analysis showed that the emotional conceptualization profiling of consumers is mostly valence-driven which confirms earlier results of product-elicited emotions studies (Danner, et al., 2016; Köster & Mojet, 2015; Ng, et al., 2013). Additionally, emotional conceptualization profiling is also arousal-driven. The level of arousal has been shown to be important for discriminating between products of a single product category (Lagast, et al., 2017; Spinelli, et al., 2015). Our results provide partly support for the importance of the level of arousal in discrimination between samples. Chocolate with private label and bio-label was linked to higher arousal emoji (e.g. 😜) and chocolate with A-label and stevia with lower arousal emoji (e.g. 😕). However, the other chocolates are not clearly linked to the arousal dimension.

This study also included a measurement of the mood before tasting the samples using the same emoji as during the main test. In contradiction to psychology research, a baseline measurement to assess consumer's mood is not common in sensory and consumer research. Danner, et al. (2016) found a weak correlation between mood and liking and moderate correlations between mood and emotions. The results presented in this paper are in line with these findings. The rather low but significant correlations between overall liking and mood supports the finding that the daily mood had little impact on overall liking of samples, which supports the validity and confirms previous research (Rossi, Borges, & Bakpayev, 2015). The observed correlations between mood and emoji after consumption confirmed the use of a within-subject design as proposed by Danner, et al. (2016). As such, we advocate the inclusion of a baseline measurement in consumer food research on emotions.

Regarding the ACQ, correlations were found for both the craving and functional score with the intensity of applicability of certain emoji. Research by Jaeger and Hedderley (2013) found that psychological traits (emotional intensity and private body consciousness) influenced the emotional conceptualization profiling of food products established by the EsSense Profile™ (King & Meiselman, 2010). Another study found that emotional words are more often used by high emotional eaters when seeing pictures of chocolate brownie (Piqueras-Fiszman & Jaeger, 2014a). The results of the present study suggest that researchers should also consider measuring psychological traits as they might influence the emotional conceptualization profiling of the samples.

One of the selection criteria was that participants had to be users of emoji during communication (e.g. text messaging, social media,…) to ensure participants were familiar with the emoji. Although this selection criteria is in line with previous research (Jaeger et al., 2017a; Jaeger et al., 2017b), this selection criteria can also be argued as a limitation. As the group of most frequent users of emoji is characterized by young adults under 30 and women (EMOGI, 2016), this is also reflected in our study population. This limits the interpretation of the findings to its specific sample population.

Furthermore, some studies have indicated that individual differences in emoticon and emoji use in computer mediated communication (CMC) tend to echo differences in psychological characteristics. For example, Hall and Pennington (2013) found that frequency of emoticon use is positively associated with extraversion and self-monitoring traits. Similarly, Settanni and Marengo (2015) found use of emoticons expressing positive sentiment in Facebook posts to be negatively associated with users' emotional distress. Additionally, emoji have been shown to have associations with three of the five personality traits (Marengo, et al., 2017). More specific, the emoji were related with the traits that have shown the most consistent links with emotions and affective processing such as emotional stability, extraversion and agreeableness (Marengo, et al., 2017). Next to individual differences, the usage and interpretation of emoji can also be culturally dependent (Miller et al., 2016). A cross-cultural comparison of emoticon usage revealed that individualistic cultures tended to use horizontal emoticons which are differentiated by mouth characteristics (e.g. :-), :-P), while collectivistic cultures tended to use vertical emoticons which are focused on eye characteristics (e.g. ^_^, T_T) (Park, Baek, & Cha, 2014). Hence, future research should also focus on the influence of socio-demographical and behavioral factors (e.g. age, cultural background, the frequency of emoji use and the familiarity with emoji).

The use of emoji can be considered as a potentially valuable source of consumer insides and might yield some implications for promotion of healthy food choices. Privitera, Brown, and Gillespie (2015) showed that the use of emoticons to label food packages (with a happy face indicating a healthy product and a sad face indicating an unhealthy product) was effective in altering grocery shoppers' perceptions of healthiness. Additionally, healthy food products with emoticon labels were chosen more often than the same foods without emoticon labels by children (Privitera, Phillips, Zuraikat, & Paque, 2015).

This study contributed to the potential of the application of emoji to assess food-elicited emotion and confirmed the applicability in products of the same category, more specific dark chocolate. The emoji approach was able to discriminate between the dark chocolate samples used in this study even when the samples had a similar mean overall acceptance. Baseline mood of the participants has found to influence the emotional conceptualization profiling, supporting the inclusion of a baseline measurement in consumer food research on emotions in future research. Additionally, future studies should investigate whether the response format influences the frequency of use when participants are tasting food products as consumers' tend to use a low number of emoji upon consumption when using a RATA response format.

4.5 References

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PART III:
IMPLICIT MEASURES OF SUBJECTIVE FOOD PRODUCT QUALITY AND FOOD PRODUCT-ELICITED EMOTIONS

Chapter 5
Applying implicit measures for sensory evaluation: An experiment on neurophysiological responses of liked and disliked solutions and drinks

This chapter is based on:

Lagast, S., De Steur, H., Schouteten, J.J., Gadeyne, S., Hödl, S., Staljanssens, W., Vonck, K., Boon, P., Gellynck, X., De Herdt, V. (2017). Neurophysiological responses in sensory evaluation: an experiment on accepted and non-accepted solutions and drinks. Under review in *Behavioural Brain Research*. IF: 3.002; R=122/259 (Q2; Neurosciences).

Abstract

Neurophysiological measures can enhance the understanding of the consumers' food experience. This study looked at neurophysiological responses to accepted (liked) and non-accepted (disliked) solutions and drinks. Responses of the autonomic nervous system as a measure for level of arousal, as well as responses of the central nervous system (frontal alpha activity, FAA) as a measure for approach/withdrawal motivational tendency, were studied.

Participants (n=32, age range: 18-34 years) were presented with a universally accepted (sucrose) and non-accepted (caffeine) solution, a personally selected accepted and non-accepted drink, and plain water. Heart rate, heart rate variability, electrodermal activity and electro-encephalography for FAA (10/20 system, 25 channels, 256 Hz) were registered during tasting. Statistical analysis consisted of linear mixed model analyses.

We found a significantly higher heart rate during tasting of the personally selected non-accepted drink and a significantly lower latency of the electrodermal response during tasting of the universally non-accepted solution and personally selected non-accepted drink. No significant results were observed for FAA.

This is one of the first studies that examined neurophysiological responses during actual tasting. This study provides an exploratory method to obtain implicit measurement of acceptance and food product-elicited emotion through neurophysiological responses and supports the importance of the inclusion of implicit measures, next to explicit measures, in sensory evaluation of food products.

Research question 4: How do neurophysiological measures contribute to the understanding of consumers' food experience?

RQ4a Which autonomic nervous system responses discriminate between different taste stimuli?

RQ4b How does frontal alpha asymmetry discriminate between different taste stimuli?

RQ4c What is the relationship between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking?

5.1 Introduction

In sensory evaluation explicit self-reported measures are traditionally used, although implicit non-self-reported measures to assess emotions and motivational behavior tendencies are increasingly advocated, in order to obtain a better understanding of consumers' food experience, such as consumers' acceptance of food products and food- elicited emotions (Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017a). Implicit measurement avoid the limitations of explicit measures, as they are indirect, non-self-reported and as such not under conscious control of the consumer (De Houwer & Moors, 2007; de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf, 2012). Hence, explicit self-reported measures could provide only limited information on taste effects. This is why clinical neurophysiological techniques could play an important role in understanding consumers' food experience (Járdánházy & Járdánházy, 2008). Unfortunately, these techniques have only been limitedly applied in sensory evaluation (Lagast, Gellynck, Schouteten, De Herdt, and De Steur, 2017).

One neurophysiological technique deals with responses of the autonomic nervous system (ANS), such as heart rate and electrodermal responses. ANS responses are described as a major component in emotional processing in many emotion theories as it can be used to measure arousal. Regarding sensory evaluation Rousmans, Robin, Dittmar, and Vernet-Maury (2000) found that electrodermal responses and cardiac responses were the most relevant ANS parameters to discriminate among different basic taste solutions and that these differences are associated with the hedonic valence. Yet, the limited literature applying ANS measurements in sensory evaluation has shown inconsistent results (Brouwer, Hogervorst, Grootjen, van Erp, & Zandstra, 2017; Danner, Haindl, Joechl, & Duerrschmid, 2014; de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014; de Wijk, et al., 2012). For example, a study on liked and disliked foods did not find significant differences in heart rate (HR) (De Wijk, et al., 2012), while another study found higher heart rates for liked compared to disliked (Brouwer, et al., 2017). Heart rate was positive associated with liking (De Wijk, et al., 2014), whereas a lack of correlation is reported in another study (Danner, et al., 2014). Regarding electrodermal responses, de Wijk et al. (2012) showed that disliked foods resulted in increased skin conductance responses and decreased finger temperature. Brouwer et al. (2017) noted higher electrodermal activity for disliked food.

A second type of neurophysiological technique that can be used to assess the consumers' food experience is electro-encephalography (EEG). The prefrontal cortex is of particular interest for emotional processing (Coan & Allen, 2004; Davidson, 2004) due to its function as a convergence zone of other interconnected structures (anterior cingulate, amygdala, hippocampus and insula). These structures are organized in two large emotional systems: the approach system and the withdrawal system. The approach system facilitates appetitive behavior and is described as a generator of positive affect. The withdrawal system facilitates moving away from aversive stimuli (Davidson & Irwin, 1999; Davidson, Jackson, & Kalin, 2000; Silva, Pizzagalli, Larson, Jackson, & Davidson, 2002). Activation of the left frontal cortex is involved in the approach system and the right frontal cortex is involved in the withdrawal system (Davidson, 2004). Hemispheric asymmetry scores (comparing the right to the left activity) of the alpha band frequency (8-13Hz) are of particular interest as positive frontal alpha asymmetry (FAA) is reported for positive stimuli and approach and negative frontal alpha asymmetry (FAA) for negative stimuli and avoidance (withdrawal) (Briesemeister, Tamm, Heine, & Jacobs, 2013). In food research, the registration of brain responses is barely applied (Brouwer, et al., 2017; Walsh, et al., 2017a; Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017b).

The present study aims to measure ANS responses (electrodermal responses (EDR), heart rate (HR) and heart rate variability (HRV)) and frontal alpha asymmetry (FAA) during consumption of universally accepted and non-accepted solutions, as well as personally selected accepted and non-accepted drinks in order to use these responses as biomarkers for product-elicited emotions and consumer's acceptance.

Organization of the autonomic nervous system and central nervous system

In this study autonomic and central nervous system (ANS and CNS) responses are studied in order to measure emotional reactions and motivational tendencies in response to taste stimuli. The perception of taste stimuli evokes physiological changes, which can be recorded by neurophysiological measures, such as EEG and ECG. These neurophysiological measures are able to go back up to the perception process and to register responses before the conscious processing of the information takes place. In order to understand the ANS and CNS responses, the organization of the ANS and CNS is described below.

The autonomic nervous system (ANS) is part of the peripheral nervous system, which includes all the parts of the nervous system located outside the CNS. The ANS system modulates peripheral functions and consist of the sympathetic and parasympathetic system, which are generally associated with respectively activation and relaxation (Mauss & Robinson, 2009). Figure 5.1 gives an overview of the peripheral components of the ANS.

The most common measures of ANS responses are based on electrodermal (i.e. sweat gland) or cardiovascular (i.e. blood circulatory system) activity (Mauss & Robinson, 2009). More details about these measures are given in the material and methods section.

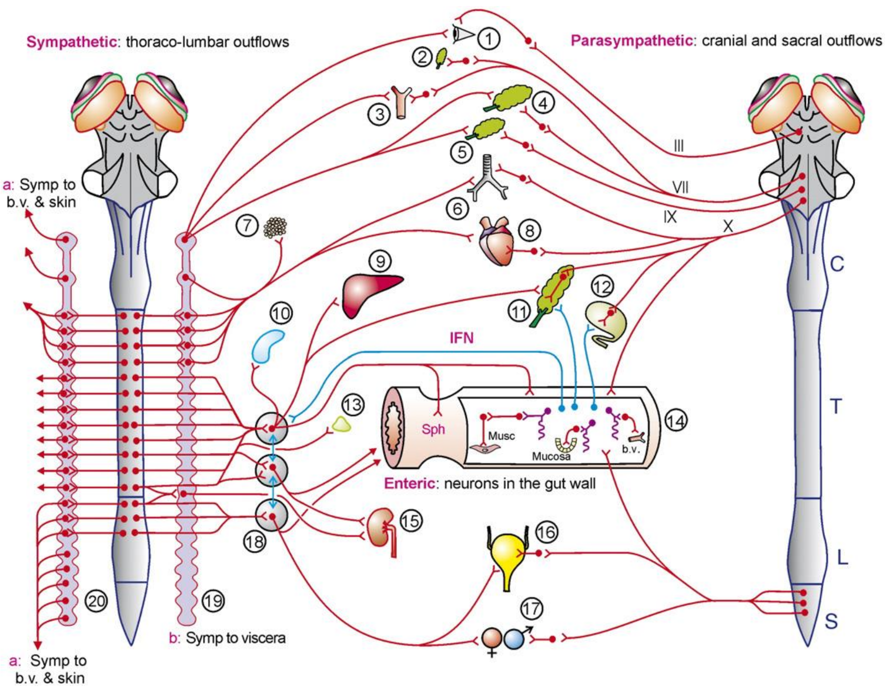


Figure 5. 1 Overview of the peripheral components of the ANS
(1) eye, (2) lacrimal glands, (3) intracranial arteries, (4, 5) salivary glands, (6) airways, (7) brown fat, (8) heart, (9) liver, (10) spleen, (11) pancreas, (12) gallbladder, (13) adrenal gland, (14) tubular gastrointestinal tract, (15) kidney, (16) urinary bladder, (17) genital organs, (18) prevertebral ganglia and plexuses, (19, 20) sympathetic chains (paravertebral ganglia and their interconnections). Spinal cord levels: C, cervical; T, thoracic; L, lumbar; S, sacral (adapted from Furness (2006)).

Arousal is a fundamental feature of behavior and is the basis of emotions, motivation, information processing and behavior responses (Groeppel-Klein, 2005). A distinction between tonic and phasic arousal can be made. Tonic arousal refers to a relatively long-term state that changes slowly due to long-lasting or extremely intensive stimuli. Phasic arousal appears in response to specific stimuli, which results in short-term variation in arousal level. Phasic arousal can be seen as the driver of decision-making processes and approach behavior (Groeppel-Klein, 2005).
The measurement of arousal consists of measurements of responses of the autonomic nervous system, such as measurement of heart rate and electrodermal activity.

The central nervous system (CNS) is composed of the brain and spinal cord. Several brain (or neural) substrates have been identified regarding the perception and evaluation of food products, emotional processing and liking.

The sensory system that serves to extract information from our environment, is an important functional subsystem of the brain. The sensory system consist of (1) unimodal processing areas that encode stimulus characteristics, (2) higher order processing unimodal areas and (3) multimodal integrative areas. Unimodal sensory areas are located at the occipital cortex (vision), the temporal cortex (audition), the frontal cortex (gustation in the insula and operculum), paralimbic cortex (olfaction in the piriform cortex), and parietal cortex (somatosensation in the postcentral gyrus). The higher order areas are involved in emotion, memory, learning and motivation. This is a very widespread network, including areas in the (para)limbic cortex (striatum, amygdala, hypothalamus), medial orbitofrontal cortex (mOFC), lateral orbitofrontal cortex (lOFC), medial prefrontal cortex (mPFC), dorsolateral prefrontal cortex (DLPFC), and anterior cingulate cortex (ACC) (Veldhuizen, 2010) (Figure 5.2)

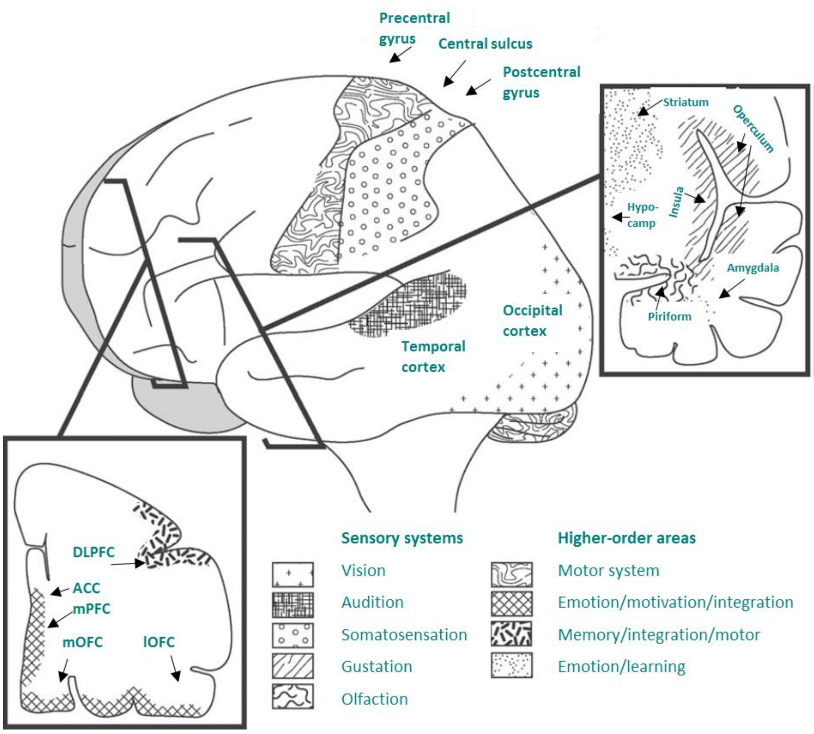


Figure 5. 2 Simplified overview of important neural substrates in the perception and the evaluation of food products
(adapted from Veldhuizen (2010)).

The neural correlates involved in emotional processing are a group of cortical and subcortical structures. These structures are interconnected in a corticolimbic network that enables a subject to generate emotional responses. Cortical structures of the affective system are the PFC, the ACC, the insular cortex, and the somatosensory cortical areas. Subcortical structures include the amygdala, hypothalamus, ventral striatum (with the nucleus accumbens) and brainstem (Damasio, et al., 2000; Price & Drevets, 2010).

Neural correlates for liking have been observed in the amygdala and orbitofrontal cortex (OFC) in neuroimaging studies (Francis, et al., 1999; O'Doherty, Rolls, Francis, Bowtell, & McGlone, 2001;

Veldhuizen, 2010; Zald, Hagen, & Pardo, 2002). Neuroimaging studies also confirmed a correlation between liking ratings and activation of the OFC for odors, tastes, and oral tactile stimuli (De Araujo, Kringelbach, Rolls, & McGlone, 2003; De Araujo, Rolls, Kringelbach, McGlone, & Phillips, 2003; Francis, et al., 1999; Guest, et al., 2007; Kringelbach, O'Doherty, Rolls, & Andrews, 2003; McClure, et al., 2004; Royet, et al., 2000).

CNS activity can be measured using different tools, such as fMRI and electroencephalography (EEG). In this research EEG is used as a tool to measure the neurophysiological responses evoked by taste stimuli. A more detailed overview of the method of EEG is given in the section material and methods.

5.2 Materials and methods

Participants

Participants were recruited at the Ghent University campus by poster advertisement and were also recruited from a database of volunteers for sensory tests. Only participants between the ages of 18 and 35 were eligible for participation. Exclusion criteria were the presence of food allergies or food intolerances, any medication intake, a history of eating or other psychiatric disorder and pregnancy for female participants.

The participants were informed about the aim of the experiment and the experimental procedure was explained in great detail to the participants. All participants reviewed and signed an informed consent prior to participation. The study was approved by the Ethics board of Ghent University Hospital (2016/0884). All participants received an incentive (coupon of 10€) for their participation.

Study design

Participants took part in two experimental sessions. Session 1 assessed their taste perception capacity and session 2 assessed their ANS responses and FAA to accepted and non-accepted solutions and drinks. All sessions took place in the morning and participants were scheduled at the same time slot for both sessions. They were not allowed to consume caffeine containing drinks (session 1) or to eat or drink anything (except water) (session 2) two hours prior the experiment. The flow of the study is depicted in Figure 5.3.

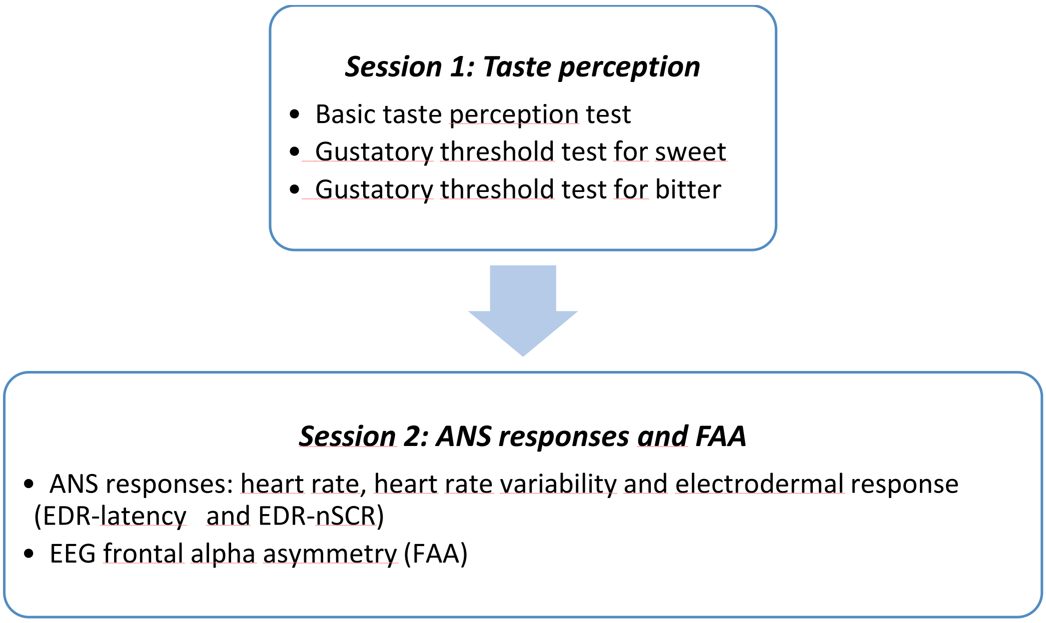


Figure 5. 3 Flow-chart of the study showing the applied measures per session

Taste stimuli

(1) *Taste stimuli for session 1: taste perception*

Taste stimuli consisted of water solutions. Sweet, salt, sour and bitter water solutions were applied for the basic taste test. Concentrations according to ISO 8586 (2012) were used (Table 5.1a). For the threshold detection tests eight concentrations were prepared for sweet (sucrose) and bitter (caffeine) solutions as specified in ISO 3972 (2011) and Hoehl, Schoenberger, Schwarz, and Busch-Stockfisch (2013) (Table 5.1b). The solutions were prepared prior to the experiment by dissolving the materials in 1 liter on a stirring hotplate under mild heat (50°C, 700 rpm) for ten minutes. All solutions were stored in glass bottles in the refrigerator at 5°C and were placed outside the refrigerator on the evening before the experiment to bring them at room temperature.

Table 5. 1 Concentration of taste stimuli used in session 1 (a) basic taste perception test and (b) gustatory threshold test. Concentrations according to ISO 8586 (2012), ISO 3972 (2011) and Hoehl, et al. (2013)

(a)	**Basic taste perception test**	
Taste	Material	Concentration (g/l)
Sweet	Sucrose (table sugar)	10 (1%)
Sour	Citric acid	0.3 (0.03%)
Bitter (2x)	Caffeine ($C8H10N4O2$)	0.3 (0.03%)
Salty	Sodium chloride	2 (0.2%)
(b)	**Gustatory threshold test**	
Solution	Sweet (Sucrose) (g/l)	Bitter (Caffeine) (g/l)
S1	12	0.27
S2	7.2	0.22
S3	4.32	0.17
S4	2.59	0.14
S5	1.56	0.11
S6	0.94	0.09
S7	0.55	0.07
S8	0.34	0.06

Note: 2x indicates that the solution was presented twice.

(2) *Taste stimuli for session 2: ANS responses and FAA*

The taste stimuli used in session 2 were a priori expected to elicit different hedonic responses. Two taste stimuli (1 accepted and 1 non-accepted) per condition (universal or personalized) were used.

For the universal condition, a universally accepted (sweet sucrose solution, Ua) and non-accepted (bitter caffeine solution, Una) solution were used as humans have an innate preference for sweet flavors and an aversion for bitter flavors (Berridge, 2000; Steiner, 1974; Steiner, Glaser, Hawilo, & Berridge, 2001; Zeinstra, Koelen, Colindres, Kok, & de Graaf, 2009). Concentration of universally accepted and non-accepted solution were determined after an initial pilot test that showed those concentrations were perceived as sweet and bitter. Universally accepted and non-accepted solutions were prepared prior to the experiment by dissolving respectively the 150 gram of sucrose on a weight-weight basis in water and 1 gram of caffeine in 1 liter water. Solutions were similarly prepared as the solutions in session 1. Solutions were stored in glass bottles in the refrigerator at 5°C and were placed outside the refrigerator on the evening before the experiment to bring them at room temperature.

The personalized condition consisted of a personally accepted (Pa) and non-accepted (Pna) drink, individually assessed by a questionnaire (Table 5.2). The personally selected drinks were purchased in Belgian supermarkets and were stored in their original containers in a refrigerator at 5°C until the evening before the experiment.

Table 5. 2 List of selected personally accepted and non-accepted drinks based on selection questionnaire. Frequency (n) and percentage (%) of selected drinks

Personally accepted drinks (Pa)	**n**	**%**	**Personally non-accepted drinks (Pna)**	**n**	**%**
Grapefruit juice (pink)	5	16%	Butter milk	8	25%
Multi fruit juice	5	16%	Tomato juice	5	16%
Orange juice	4	13%	Grapefruit juice (pink)	4	13%
Fresh orange juice	4	13%	Soy milk (natural flavor)	4	13%
Chocolate milk (Cecemel)	3	9%	Semi-skimmed milk	2	6%
Arizona Pomegranate Green Tea	2	6%	Syrup (grenadine flavor)	2	6%
Apple juice	2	6%	Ice Tea (ginger flavor)	1	3%
Pineapple juice	2	6%	Full cream milk	1	3%
Grapefruit juice (white)	1	3%	Cranberry juice	1	3%
Ice tea (apple flavor)	1	3%	Syrup (strawberry flavor)	1	3%
Soy milk (vanilla flavor)	1	3%	Red fruit milk drink (Fristi)	1	3%
Soy milk (banana flavor)	1	3%	Rice milk	1	3%
Organic fresh pear juice	1	3%	Lemon juice	1	3%

Procedure and experimental design

(1) *Procedure and experimental design in session 1: Taste perception*

Participants were invited to the Sensory Laboratory of Ghent University for session 1. Prior to arrival of the participant the solutions for session 1 were lightly shaken and then dispensed in 10 ml volumes in transparent cups labeled with a three-digit code.

During session 1 the participants had to perform three taste perception tests: (1) basic taste perception test, (2) gustatory threshold test for sweet, (3) gustatory threshold test for bitter.

First the participants had to perform a sensory basic test. This test aimed to assess the participants' capacity for detection of basic tastes (sweet, bitter, salt, sour). Seven transparent cups with 10 ml of water-solutions were presented to the participants. Two solutions contained sucrose, two caffeine, one salt, one citric acid and one plain water. Participants were instructed to take a sip of each solution and had to correctly identify the taste of each solution. Between each sample the participants had to rinse their mouth with water which was presented in the sensory booth in 120ml cups. The procedure was according to the ISO 8586 (2012) for selection of sensory panels.

Second, participants had to perform two gustatory threshold tests, one for sweet and one for bitter. These tests aimed to determine the participants' individual threshold for detection of sweet or bitter. Participants were presented with eight rounds of three transparent cups with 10 ml of liquids. The cups were labeled with a random three-digit code. Each round consisted of two presentations of water and one presentation of a solution. In each round one of the liquids was the sucrose or bitter solution (S) and two of the liquids were plain water (W). The order of the presentation of the liquids was randomized in each round and was recorded. The solutions were presented in increasing concentrations, to prevent saturation of the taste receptors (Garcia-Burgos & Zamora, 2013). Participants were instructed to take a sip of the liquid, tasting it using the whole mouth and were then instructed to spit the liquid into a separate container (sip-and spit technique). The three liquids were tasted from left to right during each round. Participants were asked to detect each round the sucrose or the bitter solution. Between each round they were instructed to rinse their mouth with water (presented in the sensory booth in 120ml cups). Participants had to complete all eight rounds and individual sucrose and bitter threshold was established as the middle solutions of three correct identifications on three consecutive rounds or the highest possible when the participant only correctly identified the last solution that was presented. This procedures was according to the ISO 3972 (2011) and similar to the procedure used in Fogel and Blissett (2014).

(2) Procedure and experimental design in session 2: ANS responses and FAA

Participants were invited to the Neurophysiological Unit of the Neurology Department, Ghent University Hospital. Prior to arrival of the participant the solutions and drinks were lightly shaken before dispensing them into labeled cups. The liquids were drawn up into syringes of 60 ml (one for each liquid). Then, a flexible tube with al length of 50 cm was connected to the syringe.

Participants were seated in a comfortable chair in front of a laptop in a room where the temperature was maintained constant (21°C). The lights in the room were dimmed to limit visual inputs. Instructions were given verbally by the experimenter and visually on the screen in front of the participant.

The experimental design of session 2 is presented in Figure 5.4a. First, the water control (six taste presentations of 10 ml of plain water) was administered. Second, the universal condition followed by the personalized condition was conducted. Each condition consisted of two randomized blocks: one with the accepted taste stimuli and one with the non-accepted taste stimuli. Each block followed 4 sequential steps: (1) two minutes pretaste baseline (no stimuli, sitting still with eyes closed); (2) six consecutive taste deliveries; (3) administration of the explicit liking score of the taste stimuli (9-point hedonic scale) and (4) a resting and rinsing period of two minutes.

For delivery of the taste stimuli (step 2) a very strict procedure was followed by the experimenter: the end of the flexible tube was put into the mouth of the participant and placed in the middle of the tongue (central position). Every taste delivery 10 ml of the liquid was administered in the participants' mouth. The experimenter was instructed by the visual cues on the laptop screen using the E-Prime 2.0 software (Psychology Software Tools, 2012): "+" pushing syringe 10 ml down (1 sec.), "taste presentation" liquid in mouth of participant (4 sec.) and "swallow" (2 sec.) instruction to swallow the liquid (Figure 5.4b).

The pretaste baseline (step 1) had two main purposes. Firstly, it served as a period to relax the participant and to bring the participant back to a neutral state in order to have a common emotional state for comparison. Secondly, it served as an extra time period between the taste deliveries to remove the effects of the previously tasted solution or drink.

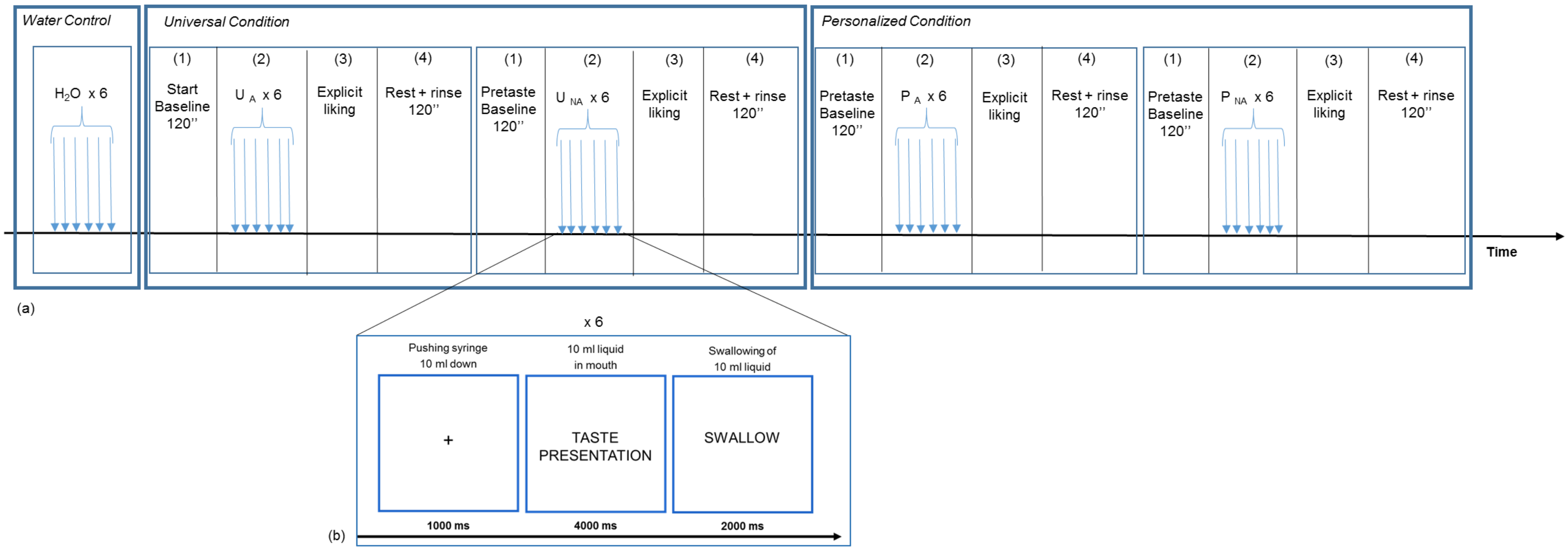


Figure 5. 4 (a) Experimental design of session 2: ANS responses and FAA indicating conditions, blocks with four steps (b) method for taste delivery

↓ indicates taste delivery.

Measurement in session 2: ANS responses and FAA

(1) <u>ANS: Electrodermal activity (EDA)</u>

Electrodermal activity (EDA) is an umbrella term used for describing autonomic changes in the electrical properties of the skin. It reflects eccrine sweat gland activity, especially those on the palms of the hand and soles of the feet, which are involved in emotion evoked sweating (Dawson, Schell, & Filion, 2007). The sweat glands are controlled by the sympathetic nervous system. As EDA is not contaminated by parasympathetic activity, it is seen as the most useful index of changes in the sympathetic arousal to emotional and cognitive states. Hence, it is closely linked to autonomic emotional processing and is widely used as a sensitive index of emotional processing and sympathetic activity (Braithwaite, Watson, Jones, & Rowe, 2013).

The two main component in the EDA complex are: (1) the general tonic level and (2) the phasic component. The general tonic level refers to the slower acting components and background characteristics of the signal. The phasic component relates to faster changing elements of the signal. The phasic processes are more event-related and are measures over shorter time spans (Braithwaite, et al., 2013). As emotions are categorized as quick responses to stimuli, this study used phasic EDA, similarly to the study of Samant, Chapko, and Seo (2017).

Furthermore, the phasic EDA can be quantified in different components. A graphical illustration of these components is given below (Figure 5.5). This study looks at the onset latency and the number of individual phasic responses. Onset latency is the time between the onset of the stimulus and the start of the electrodermal response, typically 1 to 3 seconds (Braithwaite, et al., 2013; Figner & Murphy, 2011). The number of individual phasic responses refers to the number of response peaks during a time unit.

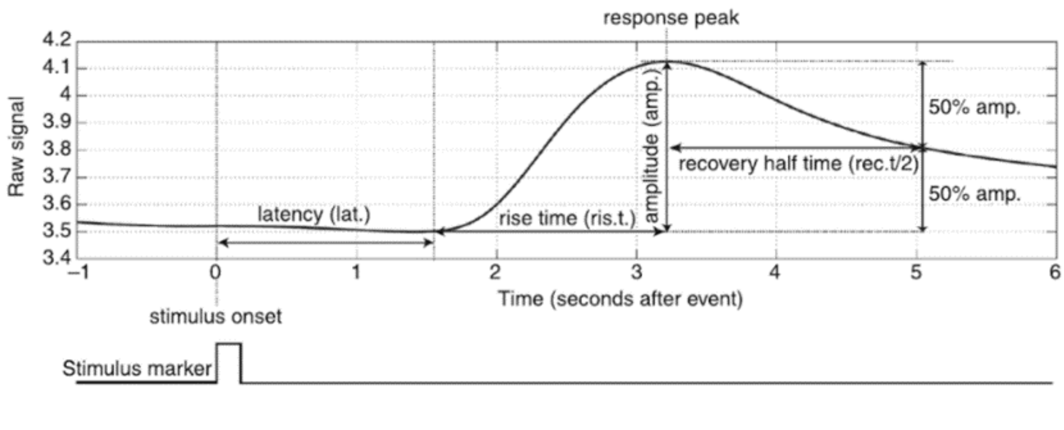


Figure 5. 5 An example of the components of an EDA-phasic component
(adapted from Figner and Murphy (2011).

(2) ANS: Cardiovascular activity (ECG)

An electrocardiogram (ECG) records the electrical activity of the heart over a period of time using electrodes placed on the skin. The waveform of the signal consist of three entities that each have a unique pattern: a P-wave, a QRS-complex, a T-wave (Figure 5.6). Of particular interest is the QRS-complex which represents the ventricular depolarization.

The ECG waveform can be quantified by use of the Pan Tompkins algorithm (Pan & Tompkins, 1985). The time domain methods rely on the series of successive RR interval values. The clearest measure is the mean value of the RR intervals or corresponding to the mean heart rate. Additionally, the variability within the RR series can be measured by the standard deviation of normal-to-normal (NN) intervals (SDNN) which reflects the overall variation, both short-term and long-term, within the RR interval series (Task Force of the European Society of Cardiology the North American Society of Pacing Electrophysiology, 1996; Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014).

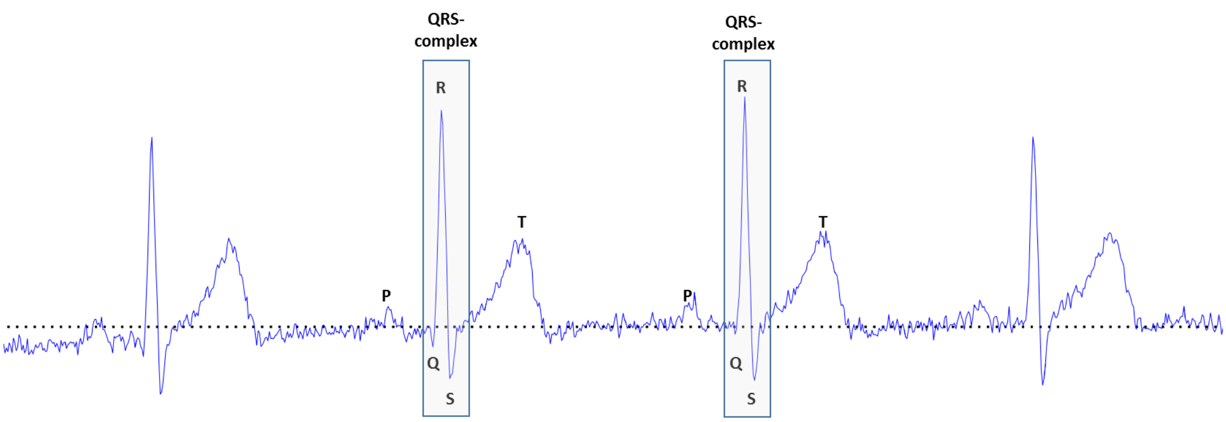


Figure 5. 6 ECG waveform with the three entities (P-wave, QRS complex, T-wave)

(3) ANS responses recording and preprocessing

In this study, the electrodermal responses were measured through two standard 8 mm Ag/AgCl electrodes placed on the thenar and hypo-thenar eminences of the palm of the non-dominant hand of the participant after controlling for hydration and temperature of environment (21˚C) (Figure 5.7). For the recording of the responses these electrodes were connected to a Micromed System Plus Headbox (Micromed, Mogliano, Italy). The signals were recorded at 256 Hz and throughout the entire experiment. Extraction of the electrodermal responses was done by use of the Matlab LedaLab toolbox (Benedek & Kaernbach, 2010). The electrodermal signals were downsampled to 32Hz and were bandpass filtered between 0.003 and 100Hz. Based on Continuous Decomposition analysis two variables were examined: the number of individual phasic responses (EDR-nSCR) and the latency of the first significant phasic response within the interval of interest (EDR-Latency).

Heart rate and heart rate variability were measured using two clip electrodes on the wrists of participant (Figure 5.7) which were connected to a Micromed System Plus Headbox (Micromed, Mogliano, Italy). Heart rate and SDNN heart rate variability were extracted from the ECG signal (sampling rate 256Hz) by use of the Matlab Pan Tompkins script (Pan & Tompkins, 1985).

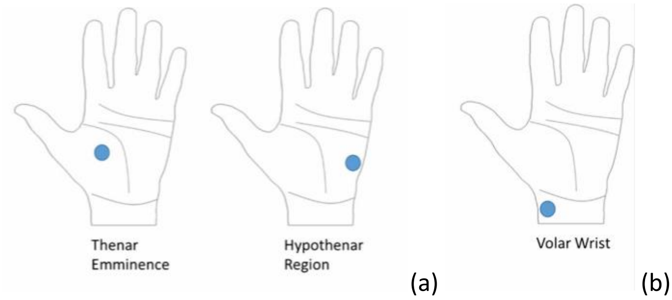


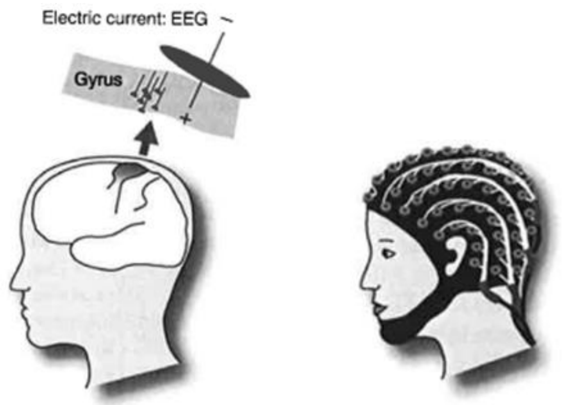
Figure 5. 7 Electrode placement for (a) electrodermal activity (b) ECG

(4) <u>FAA: Electroencephalogram (EEG)</u>

In this study brain activity (FAA) was recorded by use of electroencephalogram (EEG). EEG is a non-invasive method that measures the electric field potentials produced by the brain (King, 2004). These brain potentials can be recorded by placing electrodes on the scalp. The signals measured by EEG originates mainly from summated excitatory and inhibitory postsynaptic potentials on the apical dendrites of the cortical pyramidal neurons that are orientated perpendicular to the surface of the head (Osorio, Zaveri, Frei, & Arthurs, 2016). This indicates that scalp EEG recordings will pick up activity from the cortical gyri located near the surface of the head (Kropotov, 2010). Postsynaptic potentials arise when the flow of ions across the cell membrane of the dendrite changes because of the binding of neurotransmitters to the receptors during neurotransmission (Luck, 2014; van Putten, 2014; Veldhuizen, 2010). For detection with a scalp EEG these postsynaptic potentials need to occur simultaneously in a large number of parallel oriented neurons (Osorio, et al., 2016) (Figure 5.8 a).

In order to record the signals, electrodes are placed on the head following the international 10-20 system. Therefore, often a cap with electrodes filled with a conduction substance is attached to the subject's head (Figure 5.8 b). The recorded EEG signals represent voltage fluctuations over space and time. EEG signals are displayed as a number of graphs, in which the measured voltage (microvolt) is on the vertical axis and the time (milliseconds) on the horizontal axis. This chart can provide information about the state of the brain, for example, whether you are sleeping, being excited or relaxed (Veldhuizen, 2010).

This method has a very high temporal resolution, but a lower spatial resolution. The high temporal resolution allows for answering questions about the timing and sequential processing of information in the brain (Veldhuizen, 2010). Additionally, EEG provides a direct measure of electrical neuronal activity (Luck, 2014). Therefore, EEG is a powerful non-invasive technique for investigating the electrophysiological time-course of brain activity



(a) (b)

Figure 5. 8 Simplified picture of the EEG measurement
(a) Neural basis of the signal measures by EEG. (b) Example of an electrode cap attached to the head. Adapted from Veldhuizen (2010).

(5) <u>Advantages of EEG specific for food products</u>

In respect to food studies, EEG has a number of great advantages in comparison to other neuroimaging techniques (such as fMRI and PET). First, EEG is generally comfortable for the subject. Second, there is no sound from the equipment as compared to neuroimaging techniques (e.g. fMRI). Third, the subject can sit upright and the signal is not as sensitive to movement as other neuroimaging techniques. This allows to study the responses of participants while they are sitting in a more similar position as during normal consumption of food products. A disadvantage of EEG is that is has a low spatial resolution and thus is not suitable for studying responses of the deeper brain structures. Animal studies showed that reward and food processing brain areas are buried deep within the brain, such as the basal ganglia, the cingulate and the orbitofrontal cortex. By consequence EEG is not suitable for studying some processes that involve midline structures deep inside the scalp, for example reward learning and pleasantness coding. However, for the study of processing higher-order or cognitive aspects of food perception, such as evaluation of food products, which are processes that take place in brain areas closer to the scalp, EEG is very appropriate and powerful method (Veldhuizen, 2010). Table 5.3 gives an overview of the advantages and drawbacks of EEG.

Table 5. 3 Overview of EEG with advantages and drawbacks in comparison with fMRI and PET
Adjusted from Veldhuizen (2010) and Solnais, Andreu-Perez, Sánchez-Fernández, and Andréu-Abela (2013).

EEG	
How is brain activity measured?	Measurement of the electric field potentials produced by the brain
Technology	Electrodes placed on the head
General factors	
- Time resolution	~10-100 milliseconds
- Spatial resolution	~1 cm
Advantages	High temporal resolution (in milliseconds)
Drawbacks	Low special resolution (depending on the number of electrodes)
Factors specific to food studies	
- Naturalistic eating situation	Upright position
- Imaging of deeper brain structures	Surface only*

Note: * deeper sources can be estimated.

(6) EEG recordings and preprocessing

In this study electroencephalographic data were recorded with a Micromed System Plus (Micromed, Mogliano, Italy) using Ag/AgCl electrodes, mounted in a stretch-lycra electrode cap (WaveGuard™ EEG cap system, ANT Neuro) according to the international 10-20 system. During recording, data were referenced to electrode site CPz, while channel AFz was used as a ground. In addition to the reference and ground electrode, a total of 23 electrodes were used in this study: Fp1, Fp2, F7, F3, Fz, F4, F8, T3, C3, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2, FC5, FC6, CP5, CP6 (Figure 5.9). Signals were amplified and digitized with a sampling rate of 256 Hz, low-pass filter of 200Hz, high-pass filter of 0.4Hz and 50Hz Notch filter. Impedances were kept below 5KΩ to ensure high quality recording.

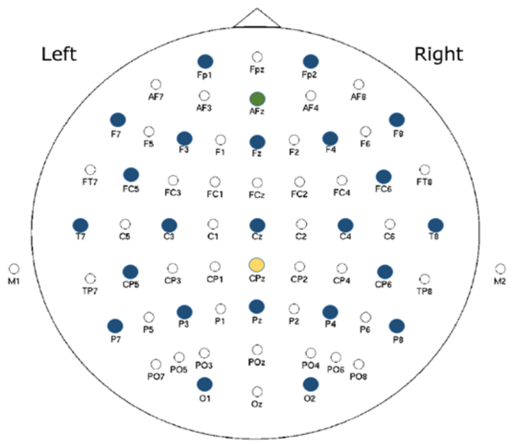


Figure 5. 9 Illustration of the 23 electrode sides (blue) together with ground (green) and reference (yellow) electrode sides applied in the study

EEG data were analyzed using BrainVision Analyzer 2 software (BrainProducts, GmbH, Gilching, Germany) and processed following the procedure commonly used in EEG-asymmetry research (Allen, Urry, Hitt, & Coan, 2004a; Allen, Coan, & Nazarian, 2004b).

The continuous EEG was first visually inspected for swallow (muscle) artifacts. Then an independent component analysis (ICA), used to subtract artifact components from each electrode, was executed to correct for vertical and horizontal eye movements, blinks and ECG artifacts. The remaining ICA components were projected back using an inverse ICA to reconstruct the artifact-free EEG. After this, the EEG signal was re-referenced to the average of all 25 recorded channels. This signal was digitally filtered with a half-power band-pass filter between 0.1–30 Hz with a roll-off of 12 dB/octave.

The four pretaste baseline measurements of two minutes were segmented based on the marker position and each two minute segments of data was then further segmented into equal sized epochs of two seconds with 1.5 second overlap, which resulted in 237 two second epochs. The taste presentations of H_2O, Ua, Una, Pa, Pna were also segmented based on the marker position at taste delivery. Each four seconds segment of data was then further divided into equal sized epochs of two seconds with 1.5 second overlap, which resulted in 30 two second epochs. These epochs were Fourier transformed to the frequency domain using the FFT, based on a Hamming window that tapered data at the distal 10% of each 2-second epoch (frequency resolution of 0.5 Hz). The total power within the alpha frequency band (8-13Hz) was extracted for pretaste baseline and the tastes (Allen, et al., 2004b; Davidson, 1988). These values were exported in Excel (Excel 2013, Microsoft Corporation, Inc. Redmond, WA). The frontal alpha asymmetry at F7 and F8 was determined through computing the relative difference between alpha as recorded at the right and the left side of the cortex as (R-L)/(R+L) x 100 (Brouwer, et al., 2017; Papousek, et al., 2014). Alpha power is considered to be inversely correlated with cortical activity (see Allen, et al. (2004b) for an extensive discussion), thus higher scores on this FAA index are indicative for relatively greater left frontal activity and lower scores suggest less left frontal activity.

Data intervals and standardization

Time markers were automatically sent to the registration system by use of a serial trigger (Schneider & Zuccoloto, 2007) using the E-Prime 2.0 software(Psychology Software Tools, 2012). These time markers identified the intervals of interest by indicating the beginning and the end of the baseline period and the delivery of the liquid. All taste presentations of H2O, Ua, Una, Pa and Pna were summed to obtain one interval of interest for each liquid for analysis (taste event H2O, Ua, Una, Pa, Pna).

The ANS responses during the water control served as a control for the ANS responses during the taste events. The water control is considered as the most appropriate and most resembling a neutral stimulus for ANS measures. The ANS responses were standardized by subtracting the value corresponding to the water control from the values of the four taste events (Brouwer, et al., 2017).

The EEG during start baseline was used as a control for the FAA during taste events. EEG during start baseline resembled the neutral brain state of the participant. For each participant, frontal alpha asymmetry was standardized by subtracting the FAA during the start baseline from the FAA during the four taste events (Brouwer, et al., 2017).

Exclusions and data loss

All ANS responses and FAA of one participant were lost due to a technical problem with the acquisition. One participant had an extreme disgust reaction during the delivery of the non-accepted drink (Pna) which caused large motor artifact in the data and therefore FAA, electrodermal responses and ECG during Pna was excluded from analysis. In two participants the water control was not recorded. In two participants FAA recordings showed large artifacts and were excluded from analysis. One ECG signal was lost in one participant.

Statistical analysis

In order to examine the effect of the taste events on the dependent variables explicit liking, heart rate, heart rate variability, EDR-Latency, EDR-nSCR, FAA and differences between accepted and non-accepted solution or drink, a linear mixed model was applied. Taste event (Ua, Una, Pa, Pna) was specified by a full factorial model with condition (U, P) and acceptance (a, na) as fixed effects and consumer as random effect. Consumers were added as random effect to account for individual differences in the dependent variables (Jaeger & Ares, 2015). Bonferroni was used for post-hoc comparison of the taste event means, adjusting for multiple testing and having set the significant level at 0.025.

In case the results were inconsistent with our a priori hypotheses, a sensitivity analysis was performed by taking the explicit liking category (explicit like, explicit dislike) as fixed effect instead of acceptance. This was done to make sure that inconsistent results were not due to individual differences in explicit liking. Additionally, explicit liking scores were added as a covariate in the linear mixed model with FAA as dependent variable.

To examine the relationship between explicit liking, ANS response, FAA and taste perception, Pearson correlation coefficients were calculated per taste event (Danner, et al., 2016).

Each taste event of each participant was checked for errors in measurement. Therefore the outliers were determined for all standardized ANS responses and FAA. Data points exceeding a deviation of 2.2 times the interquartile range (Lower: Q1-2.2(Q3-Q1); Upper: Q3+2.2(Q3-Q1)) were checked and removed if this data point was due to technical measurement errors.

All statistical analyses were performed by use of SPSS statistical software (version 24, SPSS Inc., Chicago, IL). Power analysis was conducted using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007).

5.3 Results

Participants

32 healthy participants took part in this study (16 males). The mean age was 25.5 years (SD +/- 3.7 years; range: 18-34 years). All participants (n=32) completed both sessions.

Session 1: Taste perception (n=32)

A total of 30 participants was able to detect 4 or more basic solutions correctly on the basic taste perception test. The mean gustatory threshold for sweet was 3.47 (between 4.32g/l and 2.59 g/l) and for bitter 3.00 (0.17g/l). Most participants (84.3%) were able to detect sucrose at a concentration of 1.56 g/l to 7.20 g/l. Caffeine at a concentration >0.27 was not detected by 25% of participants. The results of session 1 are depicted in Table 5.4.

Table 5. 4 Basic taste test and gustatory threshold for sweet and bitter (mean and standard error, frequency and percentage)

Basic taste	**Mean**	**SE**	**Gustatory threshold**	**Sweet**	**Mean**	**SE**	**Bitter**	**Mean**	**SE**
	5.88	0.24			3.47	0.29		3.00	0.44
Nr.	**n**	**%**	**Threshold**	**Conc. (g/l)**	**n**	**%**	**Conc. (g/l)**	**n**	**%**
0	0	0	>S1	> 12	1	3.1	> 0.27	8	25
1	0	0	S1	12.00	0	0	0.27	2	6.3
2	2	6.3	S2	7.20	9	28.1	0.22	5	15.6
3	0	0	S3	4.32	9	28.1	0.17	3	9.4
4	2	6.3	S4	2.59	4	15.6	0.14	4	12.5
5	5	15.6	S5	1.56	4	12.5	0.11	6	18.8
6	10	31.3	S6	0.94	2	6.3	0.09	1	3.1
7	13	40.6	S7	0.55	2	6.3	0.07	1	3.1
			S8	0.34	0	0	0.06	2	6.3

Session 2: ANS responses and FAA

(1) Explicit liking of the solutions and drinks

Figure 5.10 shows the explicit liking of the universal condition (Ua, Una) and personal condition (Pa, Pna). Linear mixed model analysis showed a significant main effect for taste event (Ua, Una, Pa, Pna) ($p<0.001$). Pairwise comparison tests (with correction for multiple testing) showed significant differences in explicit liking between the accepted and non-accepted solution or drink. The universal accepted solution (Ua) had a higher explicit liking compared to the non-accepted solution (Una) ($p<0.001$) and the personally accepted drink (Pa) had a higher explicit liking compared to the non-accepted drink (Pna) ($p<0.001$). These results confirmed the intended hedonic valence of the solutions and drinks.

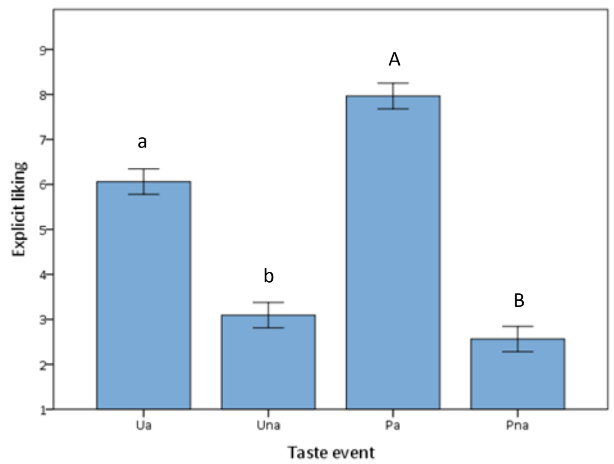
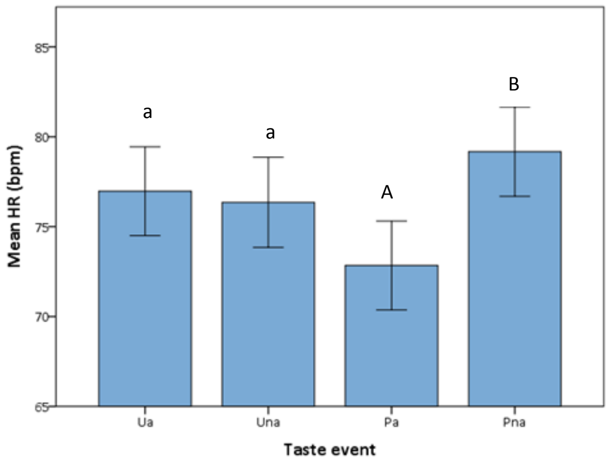


Figure 5. 10 Estimated marginal means of explicit liking scores on a 9-point hedonic scale (from 1 = extremely dislike to 9 = extremely like) for the universal condition and personal condition based on linear mixed model analyses. Error bars indicate ± standard errors of the mean. Bars within a panel with the different letters (ab for universal condition, AB for personal condition) differ significantly from each other ($p \leq 0.05$).

(2) <u>ANS responses to the solutions and drinks</u>

Heart rate showed a significant effect for taste event (p=0.009). Pairwise comparison showed a significant difference between the personally accepted (Pa) and non-accepted drink (Pna), where the personally non-accepted drink (Pna) was higher than the accepted drink (Pa) (p=0.001). Heart rate did not significantly differ between the universal accepted and non-accepted solutions (p=0.593). Heart rate variability (SDNN-HRV) showed no significant effect for taste event (p=0.252). Figure 5.11 (a, b) shows the heart rate and SDNN-heart rate variability.

(a)



(b)

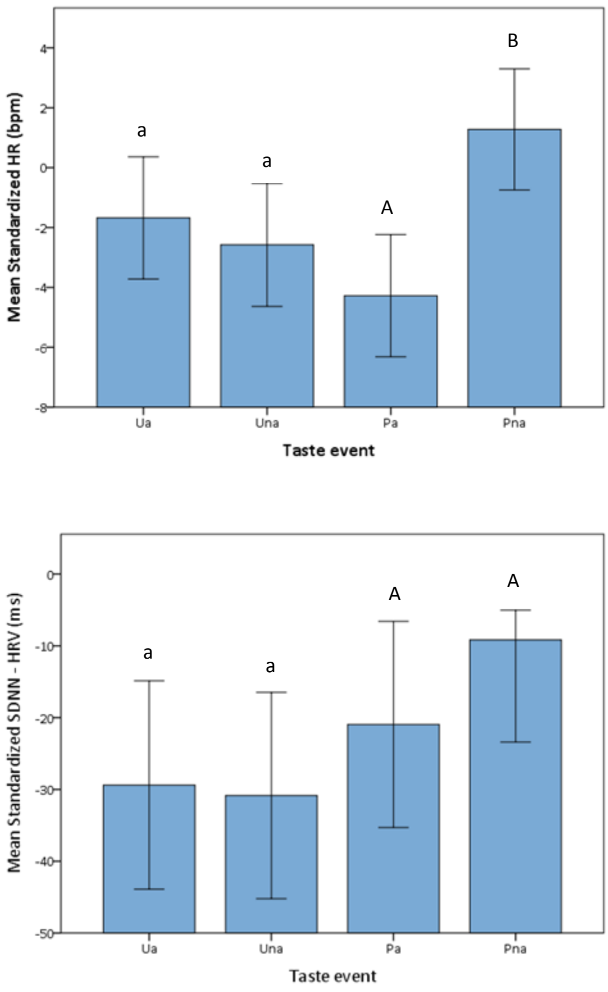
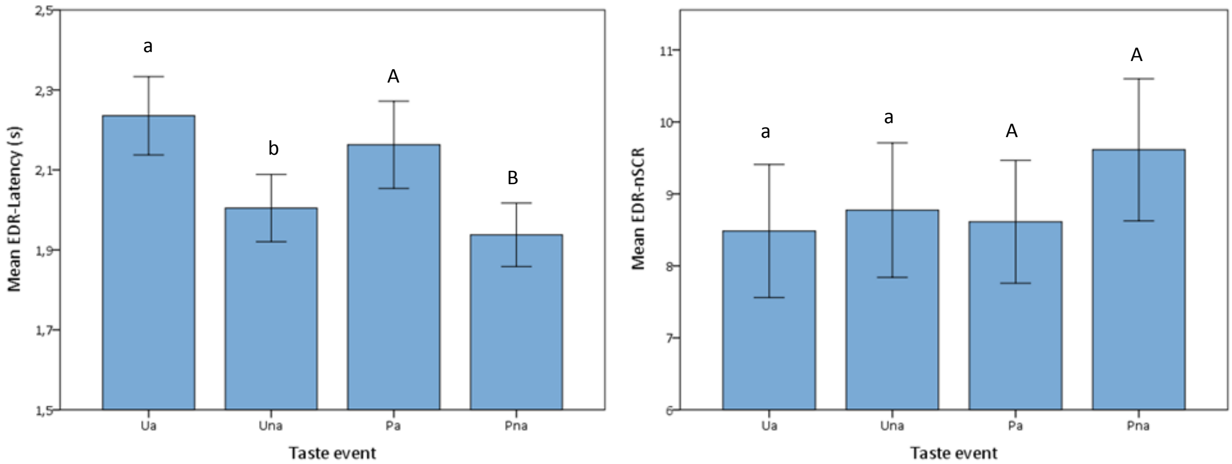


Figure 5. 11 Estimated marginal means of heart rate (beats per minute) and SDNN-HRV (ms) for the universal condition and personal condition based on linear mixed model analyses
(a) absolute data for heart rate (bpm) (b) standardized heart rate and SDNN-HRV (ms). Error bars indicate ± standard errors of the mean. Bars within a panel with the different letters (ab for universal condition, AB for personal condition) differ significantly from each other ($p \leq 0.05$).

Linear mixed model analyses on the electrodermal responses (EDR) showed a significant effect for taste event on latency (p=0.008). Pairwise comparison showed a significant difference between the universal accepted (Ua) and the universal non-accepted (Una) solution (p=0.018) and a significant difference between the personally accepted (Pa) and personally non-accepted drink (Pna) (p=0.013). Visual inspection of Figure 5.12a shows lower latency for the non-accepted solution and drink (Una, Pna) compared to the accepted solution and drink (Ua, Pa). No significant effects were observed for the number of individual phasic responses (EDR-nSCR) (p=0.587). Figure 5.12 (a, b) presents the electrodermal activity results.

(a)



(b)

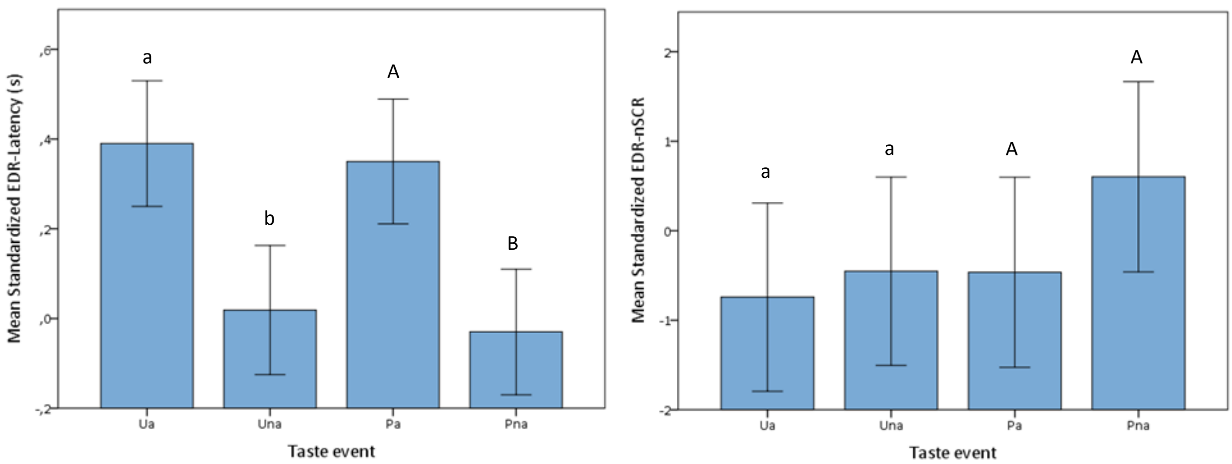


Figure 5. 12 Estimated marginal means of EDR-Latency in seconds (s) and mean EDR-nSCR for the universal condition and personal condition based on linear mixed model

(a) absolute data for EDR-Latency and EDR-nSCR (b) standardized EDR-Latency and EDR-nSCR. Error bars indicate ± standard errors of the mean. Bars within a panel with the different letters (ab for universal condition, AB for personal condition) differ significantly from each other (p ≤ 0.05).

(3) Frontal alpha asymmetry (FAA) of the solutions and drinks

Neurophysiological measurement of motivational behavior response was determined by calculating the FAA at F7F8 electrodes. Linear mixed model analysis on FAA at F7F8 showed no significant effect in mean FAA for taste event (p=0.807). Additionally, no significant effect in mean FAA was observed (p= 0.753) in sensitivity analysis with linear mixed model analyses with explicit liking as fixed effect. Taking explicit liking as covariate into account, resulted likewise in no significant effects (p=0.859), although visual inspection of Figure 5.13 shows more negative FAA scores for the non-accepted solution (Una) compared to the accepted solution (Ua) and more negative FAA scores for the non-accepted drink (Pa) compared to the accepted drink (Pna). However, this should be interpreted with caution, as large variability is observed in the data.

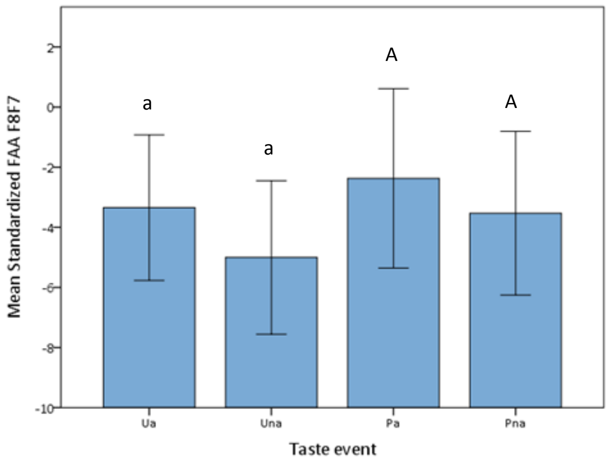


Figure 5. 13 Estimated marginal means of FAA at F7F8 for the universal condition and personal condition based on linear mixed model analyses with explicit liking as covariate (evaluated at value 4.9). Error bars indicate ± standard errors of the mean. Bars within a panel with the different letters (ab for universal condition, AB for personal condition) differ significantly from each other (p ≤ 0.05).

Relationship between explicit liking, ANS response, FAA and taste perception capacity

The results of the correlation analyses are shown in Table 5.5 and Table 5.6. Explicit liking score of the non-accepted solution (Una) was negatively associated with the score on the basic taste test (r=-0.506, n=32, p=0.003), sweet threshold test (r=-0.375, n=32, p=0.034) and bitter threshold test (r=-0.469, n=32, p=0.007). A significant positive correlation was found between frontal alpha asymmetry of the personally accepted drink (Pa) and the score on the sweet threshold test (r=0.379, n=29, p=0.043) (Table 5.5). No significant correlations were observed between explicit liking score and ANS response and FAA (Table 5.6).

Table 5. 5 Correlations between the score of the three tests (basic taste, sweet threshold and bitter threshold) and explicit liking, neurophysiological response (FAA) and physiological response (heart rate, SDNN, Latency, nSCR)

		Basic taste perception		Sweet threshold		Bitter threshold	
	n	r	p-value	r	p-value	r	p-value
Explicit liking							
- Ua	32	0.21	0.244	0.18	0.328	0.36	0.459
- Una	32	-0.51*	0.003	-0.38*	0.034	-0.47*	0.007
- Pa	31	0.22	0.226	0.17	0.350	0.13	0.497
- Pna	32	-0.19	0.308	-0.27	0.139	0.09	0.641
Neurophysiological response							
FAA							
- Ua	29	-0.05	0.779	0.26	0.180	-0.28	0.147
- Una	29	-0.35	0.060	0.23	0.225	-0.32	0.095
- Pa	29	0.10	0.611	0.38*	0.043	-0.15	0.438
- Pna	29	-0.06	0.765	0.13	0.506	-0.11	0.572
ECG - HR							
- Ua	22	-0.16	0.484	0.17	0.463	0.01	0.972
- Una	21	-0.27	0.229	-0.04	0.878	-0.11	0.625
- Pa	23	-0.24	0.266	0.24	0.266	-0.11	0.630
- Pna	23	-0.18	0.406	0.04	0.864	-0.01	0.977
ECG - SDNN							
- Ua	21	-0.09	0.711	0.28	0.222	0.22	0.335
- Una	22	-0.15	0.511	0.21	0.361	0.05	0.814
- Pa	22	-0.40	0.068	0.10	0.665	0.03	0.894
- Pna	23	-0.26	0.235	0.08	0.718	0.05	0.827
EDR – Latency							
- Ua	30	-0.26	0.165	-0.16	0.403	0.09	0.640
- Una	28	0.16	0.428	0.14	0.495	-0.09	0.653
- Pa	31	-0.30	0.107	-0.13	0.493	-0.04	0.819
- Pna	30	-0.20	0.289	-0.00	0.998	-0.19	0.322
EDR - nSCR							
- Ua	31	-0.12	0.532	-0.01	0.975	-0.29	0.115
- Una	31	-0.17	0.368	-0.01	0.797	-0.14	0.460
- Pa	30	-0.11	0.574	0.06	0.769	-0.20	0.291
- Pna	30	0.01	0.959	-0.01	0.973	0.07	0.729

Note: * = p < 0.05, FAA= frontal alpha asymmetry, ECG = electrocardiogram, HR = heart rate, SDNN = heart rate variability, EDR = electrodermal response, latency = latency of the first significant phasic response, nSCR = number of individual phasic responses, Ua = universal accepted solution, Una = universal non-accepted solution, Pa = personal accepted drink, Pna = personal non-accepted drink. All values for neurophysiological responses are standardized values.

Table 5. 6 Correlations between explicit liking and neurophysiological response (FAA), physiological response (heart rate, SDNN, Latency, nSCR)

	Explicit liking Ua		Explicit liking Una		Explicit liking Pa		Explicit liking Pna	
	r	p-value	r	p-value	r	p-value	r	p-value
FAA	0.04	0.840	0.16	0.403	-0.08	0.691	-0.25	0.183
ECG - HR	0.09	0.703	-0.00	0.996	0.08	0.728	-0.18	0.406
ECG - SDNN	0.28	0.226	0.05	0.811	-0.34	0.122	0.24	0.269
EDR - Latency	0.22	0.239	0.09	0.656	0.09	0.622	0.08	0.693
EDR - nSCR	-0.28	0.130	0.07	0.717	0.21	0.272	-0.02	0.919

Note: FAA= frontal alpha asymmetry, ECG = electrocardiogram, HR = heart rate, SDNN = heart rate variability, EDR = electrodermal response, latency = latency of the first significant phasic response, nSCR = number of individual phasic responses, Ua = universal accepted solution, Una = universal non-accepted solution, Pa = personal accepted drink, Pna = personal non-accepted drink. All values for neurophysiological responses are standardized values.

5.4 Discussion

In the present study we used neurophysiological measures (heart rate, heart rate variability, electrodermal activity and FAA) to assess acceptance and emotional associations of universally accepted and non-accepted solutions and personally selected accepted and non-accepted drinks in an implicit manner.

We found a significant difference between accepted and non-accepted drinks in heart rate and electrodermal activity, more specifically latency. This confirms the findings of Rousmans, et al. (2000) who found that cardiovascular and electrodermal responses are the most relevant ANS parameters to discriminate among different flavor solutions. Furthermore, these differences are associated with the hedonic valence: pleasant tastes induced the weakest ANS responses, whereas the unpleasant ones induced stronger ANS responses.

The increase in heart rate for non-accepted drinks can be explained by sympathetic activation of the autonomic nervous system. Heart rate is related to stress, arousal and emotions (Kreibig, 2010). General arousal leads to an increase of the sympathetic-driven responses of the autonomic nervous system, such as increased heart rate (Boucsein & Backs, 2009; Danner, et al., 2014). Ottaviani, Mancini, Petrocchi, Medea, and Couyoumdjian (2013) showed that strong sympathetic activation can be related to disgust-related avoidance and escape behavior. Heart rate has been found to respond to the valence of aroma stimuli in previous research (Alaoui-Ismaïli, Vernet-Maury, Dittmar, Delhomme, & Chanel, 1997; Bensafi, et al., 2002b): increasing heart rates in response to unpleasant aromas (Bensafi, et al., 2002a; Bensafi, et al., 2002b; Brauchli, Rüegg, Etzweiler, & Zeier, 1995; Delplanque, et al., 2009; He, Boesveldt, de Graaf, & de Wijk, 2014; Pichon, et al., 2015) whereas decreasing heart rates in response to pleasant aromas (Brauchli, et al., 1995). Although our results are in line with the findings of these studies on aromas, research studying the responses to food products is less consistent and the findings are often non-significant (Brouwer, et al., 2017; Danner, et al., 2014; de Wijk, et al., 2014; de Wijk, et al., 2012; Leterme, Brun, Dittmar, & Robin, 2008; Samant, et al., 2017). In the measurement of heart rate variability the higher arousal was not reflected in our study, which is in line with the results of Brouwer, et al. (2017). Similarly to that study, we have used short taste events to determine the heart rate variability because of the nature of the taste stimuli. Yet, heart rate variability measures may require longer intervals (Brouwer, et al., 2017). Taking the short taste events into account, we looked at heart rate variability in the time domain and compared with a baseline interval of the same length.

Electrodermal activity was measured by determining the number of phasic responses and the latency of the first significant phasic response. Earlier latencies were observed for the non-accepted solutions and drinks. Just like heart rate, electrodermal activity parameters have also been used as an indicator for arousal in physiological research and have been considered as a valid indicator for the lower arousal range as they reflect small variations in arousal state (Danner, et al., 2014; Epstein, Boudreau, & Kling, 1975; Miezejeski, 1978). Like Brouwer, et al. (2017), this study demonstrated a similar higher electrodermal activity for disliked products.

In our study neurophysiological measurement of motivational behavior response determined by frontal alpha asymmetry (FAA) at F7F8 did not show significant results. Although FAA is well documented in other research fields (for a review see Harmon-Jones, Gable, and Peterson (2010) and Briesemeister, et al. (2013)), it has only very recently been explored in food research (Brouwer, et al., 2017; Harmon-Jones & Gable, 2009; Walsh, et al., 2017a; Walsh, et al., 2017b). While mostly visual stimuli were used in these studies (Harmon-Jones & Gable, 2009; Walsh, et al., 2017a; Walsh, et al., 2017b), Brouwer, et al. (2017) also included a tasting condition. And although the latter study observed differences in FAA while frying foods, they similarly did not find any significant differences while participants were tasting them.

Regarding the relationship between explicit liking, ANS response, FAA and taste perception capacity only few significant correlations were observed. The lack of significance might be related to the small sample size used in the study. A future study could aim to work with a bigger sample size or with more repetitions of the samples in order to obtain more power for the statistical tests.

This study included very diverse stimuli that were expected to elicit different hedonic responses, namely non/accepted stimuli, both universal solutions and personally selected drinks. This was confirmed by the explicit liking scores and thus provided a valid measurement. Previous research suggested that implicit responses might be sensitive enough to detect differences in food products that are either very high or either very low in acceptability (Walsh, et al., 2017b). Studies using ANS responses and FAA also included other more diverse stimuli such as liked or disliked foods (Brouwer, et al., 2017; de Wijk, et al., 2012; Walsh, et al., 2017b). Discriminating between food products which are similar in hedonic value or neutral in hedonic value (neither like nor dislike) by using ANS responses and FAA might be even more challenging (Walsh, et al., 2017a). This applies particularly for FFA (Brouwer, et al., 2017; Harmon-Jones & Gable, 2009; Schöne, Schomberg, Gruber, & Quirin, 2016; Walsh, et al., 2017a; Walsh, et al., 2017b). This could explain why we observed more differences for the personally selected drinks in comparison to the universal solutions. Universal solutions are inherently liked (for sweet) or disliked (for bitter) (Desor, Maller, & Andrews, 1975; Kajiura, Cowart, & Beauchamp, 1992; Lipsitt & Behl, 1990). This response can be modified through experience by for example taste conditioning (Capaldi & Privitera, 2008). The personally selected drinks were probably more able to elicit stronger emotional response, however in terms of approach-avoidance they might not have been strong enough (as no significant effects for FAA were observed). Furthermore, food stimuli in general might lack the intensity to detect smaller differences. This is in contradiction to the extremely euphoric stimuli which are regularly used in psychology (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Walsh, et al., 2017a).

This study used liquid food products as stimuli to avoid movement artefact caused for example by chewing the food. Previous research has used similar solutions (Rousmans, et al., 2000) or beverages (Danner, et al., 2014; de Wijk, et al., 2014). Moreover, studies that have used solid foods have argued that the data was subject to noise because of movement artefact (Brouwer, et al., 2017; de Wijk, et al., 2012).

Of importance is the current lack of standardized methods in food research to measure ANS responses and FAA. Knowledge of appropriate baselines against which to standardize neurophysiological data in response to food are lacking. Some studies have used water (Rousmans, et al., 2000; Samant, et al., 2017) or non-food related videos (Walsh, et al., 2017a) whereas other studies have not used a baseline or control at all (Danner, et al., 2014; de Wijk, et al., 2014; de Wijk, et al., 2012; He, Boesveldt, de Graaf, & de Wijk, 2016). Emotion studies in the domain of psychology however stressed the importance of the use of an appropriate baseline or control (Davidson & Irwin, 1999). Therefore, our study has incorporated both a water control and a baseline measurement.

This study took place in a controlled setting, a neurophysiological laboratory where each participant was tested separately, to limit influencing factors. However, this has limited the ecological validity as this situation is not a very realistic eating setting. Alternatively, one could opt to simulate an eating environment. The study of Brouwer, et al. (2017) for example worked with real-life cooking, but did note quality issues with the data. As measurements of neurophysiological responses are technically more challenging, these require controlled settings to optimize quality and seem to be more suitable for laboratory environments than for real-life (de Wijk, et al., 2012). In the near future, technological advancements should make it possible to carry out tests in an immersive or virtual context (Astur, Carew, & Deaton, 2014; Yelshyna, et al., 2016). This would allow having the best of two worlds: the laboratory context under controlled circumstances versus the more realistic consumption context.

As implicit measures are very new in food research, this study examined ANS responses and FAA to accepted and non-accepted solutions and drinks. Further research is needed to optimize, standardize and validate these implicit measures suitable for food. This research supports the importance of the inclusion of implicit measures, next to explicit measures, in sensory evaluation of food products.

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PART IV:

GENERAL DISCUSSION AND FUTURE PERSPECTIVES

Chapter 6
Discussion, conclusions and future

The previous parts and corresponding chapters present the study-specific findings and discuss the study limitations in detail. This final chapter provides a general discussion of the main findings and conclusions in view of the research objective and research questions out-lined in chapter 1 of part I. First, the research objective and research questions are revisited. Second, the scientific research contribution is described. Third, the limitations of this doctoral research are acknowledged and future perspectives and opportunities for further research are proposed. Finally, practical relevance and implications of the doctoral thesis for food companies are provided.

6.1 The research objective and research questions revisited

The general objective of this doctoral dissertation was to examine both explicit and implicit consumers' responses contributing to a better understanding of the consumers' food experience. The research started with explicit self-reported measures traditionally used in sensory and consumer research and moved beyond these self-reported measures by examining implicit measurements of food product acceptance and food product-elicited emotions. Four different ways to measure the consumers' food experience were examined in this dissertation: (a) traditional, explicit verbal measurement by use of a consumer-defined emotional lexicon (chapter 3), (b) explicit, non-verbal measurement by use of an emoji-based questionnaire (chapter 4), (c) implicit measurement of brain activity looking at frontal alpha asymmetry (chapter 5) and (d) implicit measurement of autonomic nervous responses looking at heart rate, heart rate variability and electrodermal activity (chapter 5).

Based on the conceptual framework, three research objectives corresponding to the three main parts of the dissertation were formulated. In total four research questions and twelve subquestions were defined. Each of these questions is discussed in the following sections. An overview of the research objectives, research questions and key findings is presented in Table 6.1.

Table 6. 1 Overview of research objectives, research questions and key findings

Research objectives	Research questions		Key Findings
1: Provide a comprehensive overview of measurements of food product-elicited emotion in sensory and consumer research	*RQ1*	*What measurements are used in sensory and consumer research to assess consumers' food product-elicited emotions?*	*Dominance of explicit (52) over implicit (12) or combined (6) methods* *Recent trend of implicit methods as an emerging interdisciplinary tool*
	RQ1a	*How is food product-elicited emotion measured in sensory and consumer research?*	*Explicit methods use rating, CATA and RATA response formats, whereas implicit methods apply continuous registration of food product-elicited emotion*
	RQ1b	*What type of products are used for measurement of food product-elicited emotion?*	*Explicit methods more often target highly accepted products*
	RQ1c	*How do the sample descriptives (sample size, age groups, gender) of the studies differ for each method?*	*Smaller sample sizes and younger adult participants for studies using an implicit method.* *Independently of the method type studies had more female participants*
2: Examine consumers' acceptance and explicit verbal and non-verbal emotional conceptualization profile of dark chocolates	*RQ2*	*How does a more positive, explicit verbal emotional conceptualization profile discriminate between dark chocolate?*	*Dark chocolate with sugar and with tagatose were different on the arousal level of emotional conceptualizations. On the valence level sugar and tagatose did significantly differ from stevia but not from each other.*
	RQ2a	*How do the overall liking scores and the sensory profiles differ for dark chocolates with two low-calorie sweeteners in relation to dark chocolate with sugar?*	*Low-calorie sweetener tagatose in dark chocolate is more similar to sugar than low-calorie sweetener stevia on overall liking and on sensory attributes texture, bitterness, duration of aftertaste and intensity of aftertaste*
	RQ2b	*In what manner do the explicit verbal emotional conceptualizations discriminate between dark chocolates with different low-calorie sweeteners?*	*Dark chocolate with stevia elicited mostly negative emotional conceptualizations* *Dark chocolate with tagatose associated with positive emotional conceptualizations*

Table 6. 1 (*Continued)*

Research objectives	**Research questions**		**Key Findings**
2: Examine consumers' acceptance and explicit verbal and non-verbal emotional conceptualization profile of dark chocolates	*RQ2c*	*To what extent is consumers' emotional eating behavior related to emotional conceptualizations of dark chocolates?*	*Consumers with high emotional eating behavior selected a larger number of emotional terms*
	RQ2d	*To what extent are consumers' health and taste attitudes related to acceptance of dark chocolates?*	*No significant differences were found between the categories of the health and taste attitudes and acceptance of the dark chocolates.*
	RQ3	*To what extent do emoji as a non-verbal explicit measure contribute to the measurement of food product-elicited emotion?*	*The emoji approach was able to discriminate between products of a single product category (dark chocolate)*
	RQ3a	*In what manner do the explicit non-verbal emotional conceptualizations discriminate between different dark chocolates?*	*Positive emoji for higher liked samples, negative emoji for lower liked samples*
	RQ3b	*What influence has baseline mood on the non-verbal emotional conceptualizations?*	*Positive emoji were associated with a positive baseline mood and negative emoji were associated with negative baseline mood*
3: Examine implicit measures of subjective food product quality and food product-elicited emotion during consumption	*RQ4*	*How do neurophysiological measures contribute to the understanding of consumers' food experience?*	*Neurophysiological measures (heart rate and EDA response) were able to discriminate between accepted and non-accepted solutions and drinks*
	RQ4a	*Which autonomic nervous system responses discriminate between different taste stimuli?*	*Significant higher heart rate for non-accepted drink and significant changes in electrodermal activity (lower latency time) for non-accepted solutions and drinks*
	RQ4b	*How does frontal alpha asymmetry discriminate between different taste stimuli?*	*No significant difference, but more negative FAA scores for non-accepted solutions and drinks*
	RQ4c	*What is the relationship between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking?*	*No significant correlations were observed between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking*

PART I: General introduction

Research objective 1: to provide a comprehensive overview of measurements of food product-elicited emotion in sensory and consumer research

Research question 1: What measurements are used in sensory and consumer research to assess consumers' food product-elicited emotion?

RQ1a How is food product-elicited emotion measured in sensory and consumer research?

RQ1b What type of products are used for measurement of food product-elicited emotion?

RQ1c How do the sample descriptives (sample size, age groups, gender) of the studies differ for each method?

The systematic review identified 70 studies. Out of the 70 studies, a total of 52 studies used an explicit method, 12 studies used an implicit method and 6 studies used both methods. Each measurement and the corresponding number of studies are presented in Figure 6.1.

The review identified a widespread use of explicit methods, of which the verbal self-reported measures are the most applied. The emotional lexicon, either predefined or consumer-defined, is the most used. Non-verbal measurement was applied in less studies.

Implicit methods are limitedly used in consumer and sensory research. Three types of measures were identified within the implicit methods: expressive measures (which were the most applied), physiological measures and implicit behavioral task measures. The review noted an increased interest in applying implicit methods in consumer and sensory research.

Most implicit measurements are registered continuously while explicit methods obtain data at certain points in time (e.g. filling in a questionnaire during or after consumption). Within the explicit methods, three types of response formats are commonly used: rating, CATA and RATA.

Differences in type of products used for the assessment of food product-elicited emotion were observed, with the explicit methods targeting highly accepted products, such as chocolates and fruit juices. Implicit methods on the other hand choose more frequently products with low consumer acceptance level, such as negative fish odors.

Studies using an implicit method had smaller sample sizes and targeted a younger adult participants. Although most studies targeted mixed gender groups, the proportion of female participants was higher than the proportion of men participating in the studies.

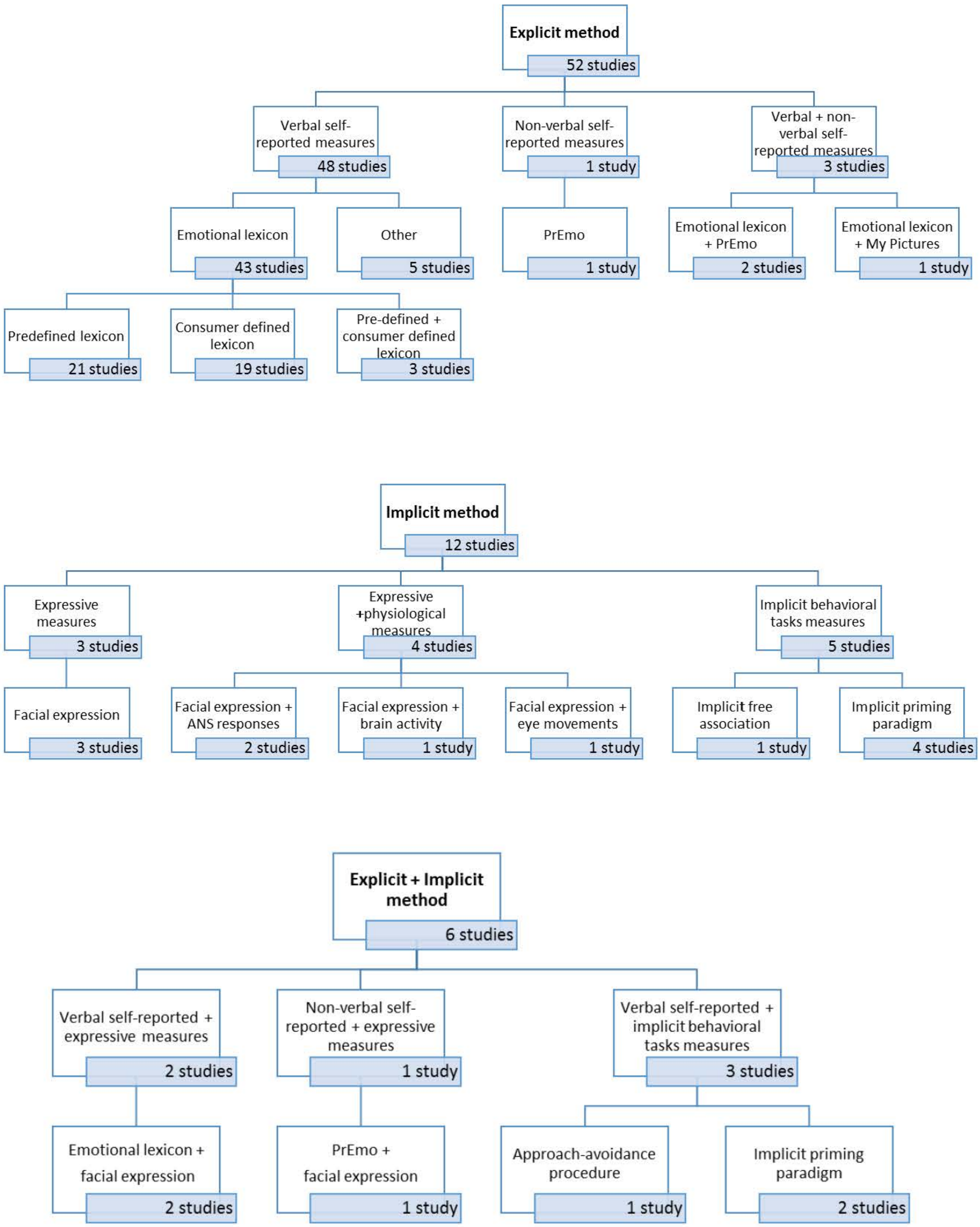

Figure 6. 1 Overview of each measurement and corresponding number of studies

PART II: Explicit measures of subjective food product quality and food product-elicited emotions

Research objective 2: to examine consumers' acceptance and explicit verbal and non-verbal emotional conceptualization profile of dark chocolates

Research question 2: How does a more positive, explicit verbal emotional conceptualization profile discriminate between dark chocolates?

RQ2a How do the overall liking scores and the sensory profiles differ for dark chocolates with two low-calorie sweeteners in relation to dark chocolate with sugar?

RQ2b In what manner do the explicit verbal emotional conceptualizations discriminate between dark chocolates with different low-calorie sweeteners?

RQ2c To what extent is consumers' emotional eating behavior related to emotional conceptualizations of dark chocolates?

RQ2d To what extent are consumers' health and taste attitudes related to acceptance of dark chocolates?

Dark chocolate with sugar and with tagatose elicit comparable positive emotional conceptualizations. In terms of overall acceptance the chocolate with tagatose did not differ from the chocolate with sugar. However, these chocolates were different on the activation dimension and thus the emotional conceptualization profiling was next to valence driven, also arousal (or activation) driven. In this study the level of arousal (or activation) is shown to be an important dimension for discriminating between products of a single product category.

Overall the low-calorie sweetener tagatose in dark chocolate was perceived as more similar to sugar than the low-calorie sweetener stevia. Significantly lower overall liking for dark chocolate with stevia as low-calorie sweetener was observed as compared to dark chocolate with sugar or with the other low-calorie sweetener, tagatose. Four out of five sensory attributes investigated in the study namely; texture, sweet flavor, bitter flavor and duration of aftertaste were found to be significant different between the two low-calorie sweeteners.

Dark chocolate with tagatose and dark chocolate with sugar were significantly more associated with positive emotional conceptualizations. Chocolate with stevia on the other hand elicited mostly negative emotional conceptualizations. These results confirm recent studies that have stressed the added and unique information of emotional responses to food, which can give new information for product development (Cardello, et al., 2012; Gutjar, et al., 2015b; King & Meiselman, 2010; Thomson, Crocker, & Marketo, 2010).

Participants older than 46 years had a lower overall liking for the dark chocolate with tagatose. No differences for emotional eating behavior or health and taste attitudes on overall liking were observed. The emotional conceptualization profile was linked to the consumption of the chocolates and the emotional eating behavior of the participants. The results showed that the group of high emotional eaters selected on average a larger number of (positive) emotional terms than the low and moderate emotional eaters across all dark chocolates.

Research question 3: To what extent do emoji as a non-verbal explicit measure contribute to the measurement of food product-elicited emotion?

RQ3a In what manner do the explicit non-verbal emotional conceptualizations discriminate between different dark chocolates?

RQ3b What influence has baseline mood on the non-verbal emotional conceptualizations?

The emoji approach was able to discriminate between the dark chocolate samples used in the study, even when the samples had a similar overall acceptance. This supports the applicability of emoji-based questionnaires with products of the same category, more specific dark chocolate. Additionally, it broadens the use of non-verbal instruments as a very recent type of non-verbal instruments next to PrEmo (Desmet, 2003).

Significant differences among the chocolate samples were found in five out of 33 emoji: *smiling face with smiling eyes* 😊, *grinning face* 😀, *face with stuck out tongue and winking eye* 😜, *expressionless face* 😑 and *confused face* 😕. As expected, positive emoji were more used for the higher liked samples. Two emoji (*face with stuck out tongue and winking eye* 😜 and *expressionless face* 😑) were able to discriminate between four equally liked samples. The *expressionless face* emoji 😑 was able to discriminate between all five chocolate samples and was significantly more used for dark chocolate with stevia (which had a lower overall liking).

Baseline mood influenced the emotional evaluation, positive emoji were associated with a positive baseline mood and negative emoji were associated with negative baseline mood. Additionally, rather low but significant correlations between overall liking and mood were observed. This supports the finding that the daily mood has limited impact on overall liking of samples (Rossi, Borges, & Bakpayev, 2015), which contributes the validity.

PART III: Implicit measures of subjective food product quality and food product-elicited emotions

Research objective 3: to examine implicit measures of subjective food product quality and food product-elicited emotion during consumption

Research question 4: How do neurophysiological measures contribute to the understanding of consumers' food experience?

RQ4a Which autonomic nervous system responses discriminate between different taste stimuli?

RQ4b How does frontal alpha asymmetry discriminate between different taste stimuli?

RQ4c What is the relationship between frontal alpha asymmetry, autonomic nervous system responses and explicit overall liking?

An exploratory method to examine implicit measurement of acceptance and food product-elicited emotion through neurophysiological responses is provided in chapter 5. The study shows that ANS responses, heart rate and electrodermal activity, are able to discriminate between the taste stimuli used in this study and hence contribute to food product-elicited emotion. Frontal alpha asymmetry on the other side showed no significant differences, and the manner how it contributes to acceptance still needs further research.

A significant difference between accepted and non-accepted drinks was observed in heart rate and electrodermal activity. This confirms the findings of Rousmans, Robin, Dittmar, and Vernet-Maury (2000) who stated that cardiovascular and electrodermal responses are the most relevant ANS parameters to discriminate among different flavor solutions. Furthermore, these differences are associated with the hedonic valence: pleasant tastes induced the weakest ANS responses, whereas the unpleasant ones induced stronger ANS responses.

FAA is related to our motivational tendency behavior, such as approach or avoidance motivation. FAA did not show significant results, but a more pronounced negative FAA score for the non-accepted solution compared to the accepted solution and a more pronounced negative FAA score for the non-accepted drink compared to the accepted drink was observed. This corresponds to a higher avoidance motivational response for the non-accepted solution and drink.

Although expected, no significant correlations were observed between FAA, autonomic nervous responses and explicit overall liking. The lack of significance might be related to the small sample size used in the study.

6.2 Research contributions

This section describes the methodological and empirical contribution of this doctoral thesis. The major research contributions of this doctoral dissertation refer to:

- First systematic review on food product-elicited emotions providing an exhaustive overview of the methods, measurements and instruments that are currently applied in sensory consumer research (Chapter 2).
- The inclusion of both explicit and implicit responses to examine subjective food product quality and food product-elicited emotions (Chapter 3, 4, 5).
- New insights on the interrelation between the sensory aspects and the explicit food product-elicited emotions based on verbal and non-verbal emotional conceptualization profiling (Chapter 3 and 4).
- The methodological innovative implementation of neurophysiological measures as a measurement of implicit responses in sensory evaluation by conducting the first experimental sensory consumer research to study the influence of tasting liked and disliked food products on consumers' neurophysiological responses (Chapter 5).

6.2.1 Methodological contributions

This doctoral research uses measurement of explicit and implicit responses to obtain a better understanding of consumers' food experience. The explicit measures exist of a verbal measurement of food product-elicited emotions (consumer-defined emotional lexicon) and a non-verbal measurement of food product-elicited emotions (emoji-based questionnaire). The implicit measures are based on neurophysiological measurement of acceptance (frontal alpha asymmetry) and neurophysiological measurement of food product-elicited emotions (autonomic nervous system responses).

The explicit measures to assess food product-elicited emotions are most commonly used in consumer and sensory research. However, the assessment of product-elicited emotions in consumer and sensory research is still very recent and food researchers are encountered with the challenge of how to accurately measure food product-elicited emotions (Samant, Chapko, & Seo, 2017). The most applied approach in consumer and sensory research is the use of explicit verbal measurement (Lagast, Gellynck, Schouteten, De Herdt, & De Steur, 2017). By adding explicit verbal emotional conceptualization profiling during sensory evaluation, this research contributes to the growing literature on emotional conceptualizations in sensory evaluation by extending it. Looking to overcome the issues of verbal explicit measurements, the second chapter of part II zooms in to the use of emoji-based questionnaire instead of emotional lexicons to measure explicit non-verbal emotional conceptualizations. The emoji-based questionnaire is a first step in the effort to objectify self-reported measures. Non-verbal measurement can be considered as one step closer to a more intuitive measurement of emotional conceptualizations as consumers do not need to verbalize. Additionally, the use of emoji can also offer an intuitive and informal way to express emotions (Walther & D'Addario, 2001), based on a self-reflective (and as such still explicit) facial expression approach. Additionally, the threshold and cognitive effort of participants is lowered, making the data more reliable and the overall collection and processing of data more efficient.

Implicit measures to identify consumers' acceptance and food product-elicited emotions have only been limitedly applied in consumer and sensory research (Lagast, et al., 2017). Implicit measures as an emerging interdisciplinary tool to obtain a better understanding of implicit or unconscious emotions and motivational behavior tendencies can lead to a better assessment of consumers' food experience. The methodological novelty is the implementation of neurophysiological measures to assess implicit responses in a consumer experiment. It is the first time that neurophysiological responses (including frontal alpha asymmetry) are measured during consumption which is a major innovative methodological contribution in the field of sensory science. Furthermore, the experiment adds to the existing literature on neurophysiological responses in emotional and motivational research. This doctoral thesis contributes to the methodology in sensory research by indicating that there are clear opportunities and gains to implement implicit measures in sensory evaluation.

6.2.2 Empirical contributions

The empirical contribution of this doctoral research is to be found primarily in the application and implementation of the measurement of both explicit and implicit responses in sensory evaluation of food products.

In part I a critical review is provided on the methodologies applied in sensory and consumer research to assess food product-elicited emotion. The increasing interest in emotional associations in consumer and sensory research has led to the introduction of many emotional instruments to capture consumers' emotions elicited by food (Dalenberg, et al., 2014; Köster & Mojet, 2015). The review presents studies in which sensory analysis and measurement of food-product-elicited emotions are combined and it identifies two methods for assessing food product-elicited emotions: explicit and implicit methods. Being the first systematic review, this narrative synthesis provides an exhaustive overview of the methods, measurements and instruments that are currently applied in consumer and sensory research and as such it contributes to literature on food product-elicited emotions and may prompt researchers to understand the consumers' food experience by building appropriate research designs including these innovative, implicit or combined approaches based on the reviewed studies.

Part II studies the interrelation between the sensory aspects and the explicit food product-elicited emotions. Next to liking, an emotional conceptualization profile can provide new information to product developers (Cardello, et al., 2012; Gutjar, et al., 2015a; King & Meiselman, 2010; Thomson, et al., 2010). Previous research has studied the explicit emotional conceptualization profiles for different food products. In this dissertation, the novelty is that explicit emotional conceptualization profile is examined within one product group. Different types of dark chocolate are used: dark chocolate with low-calorie sweeteners such as tagatose and stevia, dark chocolate from A-label and private label and dark chocolate from private label with bio-label. The research here studies if these explicit emotional conceptualization profiles can discriminate between products of the same product category but different in sensory characteristics and which emotional conceptualizations are associated with acceptance. The insights obtained contribute to a better understanding of the consumers' food experience.

Finally, in part III, neurophysiological measures were implemented to assess implicit reponses in a consumer experiment. It covers the interesting and innovative use of implicit measures in sensory evaluation and shows the discriminating capacity of some neurophysiological variables. This research contributes to the influence of tasting liked and disliked food products on consumers' neurophysiological responses. It provides a stepping stone to examine the differences between explicit and implicit evaluations of food products and to close the knowledge gap of the difference between explicit and implicit evaluations. Understanding the difference and the interaction between explicit and implicit acceptance and food-product-elicited emotions can help to broaden the understanding of the consumers' food experience.

6.3 Limitations and future research

This doctoral thesis comprises both explicit and implicit responses and contributed to a better and broader understanding on how consumers experience food products. However, there are limitations associated with this doctoral research which are thoroughly discussed in chapters 2 to 5. This section will focus on the general limitations which need to be acknowledged and are mainly inherent when conducting sensory research. These limitations also open up opportunities for further research.

Sampling

The methodologies used for sampling and data collection applied in this doctoral thesis imposed some limitations. In all studies, a convenience sampling approach was used, which is exposed to a sampling bias. The use of convenience samples limit the interpretation of the findings to its specific sampling frame. Further validation is needed in order to extrapolate to other populations. Future studies should similarly test the robustness of these findings using samples in other locations.

All studies were conducted in Flanders and thus pertains to its narrow geographic scope. Additionally, almost all participants were recruited through the SensoLab database of volunteers for sensory tests, which consists mainly of students or employees of the faculty. As a consequence, there is sample bias towards younger and higher educated consumers. Moreover, intercultural differences exist in emotional associations. For example van Zyl and Meiselman, 2015 showed more discrimination between products for positively valenced terms in English speaking terms while the discrimination was equal for positively and negatively valenced terms in Spanish speaking terms. Additionally, one should also consider that the same language can lead to different interpretations when persons of different cultures are involved, as reported by van Zyl and Meiselman (2016).

Participants were also not allowed to have allergies nor food intolerances, which limits the interpretation of the result to a healthy population. A challenge for further research is to include participants with allergies or food intolerances without breaching ethical regulations as this target group could benefit from product development catered to their needs and requirements. This target group could also be broadened with other pathologies with specific dietary needs such as diabetes and obesity or with Parkinson or stroke patients.

Based upon recommendations from previous research (King & Meiselman, 2010), the studies in the doctoral research have opted to include only product users. The inclusion of non-product users might offer new insights. First exposure to a product might issue interesting effects easily registered through explicit but especially through implicit measures. Liking might be a determinant for future consumption and purchasing behavior as an initial positive experience might flatten out over time. First, exposure might also be relevant for novel food development such as insect based products, where product users are scarce and often biased to favor a product as early-adopters or through ideology (e.g. ecological reasons).

The doctoral research has examined implicit measures, yet chapter 5 is based on a small sample size. Although studies using implicit measures have generally small sample sizes (see also chapter 2), the evolution and better understanding of implicit measures should lead to future studies with larger and more statistically representative samples in order to obtain more power for the statistical tests. To reach larger sample sizes, the practical limitations need to be addressed. These practical limitations include the availability and use of equipment, and transferring and interpreting the obtained data. A standard protocol with clear steps on use, data transfer and interpretation would facilitate researchers and allow them to gain time to apply implicit measures to a broader sample size. The development of protocols is advised for future research.

Explicit measures

The studies in chapter 3 and 4 rely on explicit self-reported measures to assess the emotional associations upon consumption. These measures are commonplace in consumer and sensory research, as shown in the systematic review in chapter 2. Explicit measures remain a popular approach among practitioners in consumer and sensory research, because they are quick in use and the data is easy to process (Dorado, Perez-Hugalde, Picard, & Chaya, 2016) and are user-friendly as they do not require much involvement of the participant (Jaeger, Cardello, & Schutz, 2013). Although these measures provide valuable insights and have attributed tremendously to sensory science, they likely suffer from social desirability and self-representation biases (Chai, et al., 2014; Danner, Sidorkina, Joechl, & Duerrschmid, 2014). The biases part and parcel of explicit self-reported measures create an inconsistency between what explicit and implicit methods measure, despite the uniform terminology in the literature. The explicit self-reported measures assess emotional conceptualizations rather than the emotional response (Thomson & Crocker, 2015). Emphasis is often put on what the product is communicating to the consumer instead of what the product is really doing to them (Thomson et al., 2010), what implicit measures try to assess (see further 6.2.3). A further understanding of the difference between emotional, functional and abstract conceptualizations in explicit measures, as noted by Thomson & Crocker (2015), can help researchers to better understand the consumers' food experience. In the literature, the terminology applicable for results of explicit (and consequently implicit) measures needs to be re-established by clearing out the differences and nuances between conceptualizations and responses.

Implicit measures

The study in chapter 2 mapped the use of implicit measures. A functional selection of those implicit measures is applied in the study of chapter 5. In chapter 5 emotional response and motivational behavior tendencies (approach and withdrawal behavior) were measured through neurophysiological measures. Although the advantage of implicit measures is that they avoid the limitations of the explicit measures, they are not frequently applied in sensory science.

In sensory science the lack of an abundance of neurophysiological implicit measures can be related to some challenges. Overall, three challenging characteristics of neurophysiological measures prevail: they are complex, not-user friendly and time consuming. Firstly, the implicit measures rely on sophisticated instruments, which are not standard available in a sensory laboratory. The use of the equipment is not self-explanatory and requires a minimum degree of training and practice in order to record clear signals and as such produce qualitative data. Secondly, the interpretation of the recorded data is not straight-forward. The data needs to be filtered and preprocessed before statistical analyses can be performed. Thirdly, the absence of uniform examples and clear protocols requires ingenuity from the researchers. A standardization of the process (both to administer the measures as well as to preprocess and analyze the data) should be the aim of future research as this will boost the use and understanding of neurophysiological implicit measures. A multidisciplinary cooperation can help to overcome some of the problems, next to adding more insights into the research. Although food research tends to be multidisciplinary, when looking into setting up implicit measures, finding colleagues in other fields in which implicit measures are common-place is again a challenge.

The study in chapter 5 opted for a functional and innovative selection of neurophysiological implicit measures. As a consequence, other implicit measures such as facial expression were not used. Future research should, for example, determine which implicit measures are most functional in which context. By experimenting with and comparing expressive responses (e.g. facial expression), neurophysiological responses (e.g. skin conductance and brain activity) and implicit behavioral tasks (e.g. IAT), future research can expand the field of the non-self-reported and implicit measurement of emotions (Köster & Mojet, 2015).

The choice made for ANS responses and frontal alpha asymmetry has its own limitations. Among the ANS responses, the study in chapter 5 looked at a limited number of parameters of cardiovascular and electrodermal activity. Respiratory responses and other parameters of cardiovascular and electrodermal activity were not registered. Kreibig (2010) mapped ANS responses and parameters and rightfully suggests to look at patterns of several (parameters of) ANS responses rather than at unique signals. A complete combination of all parameters of ANS responses seems practically impossible, yet finding the most correct parameters should be a goal for future research. Future research should look into the different ANS responses and parameters and their interconnectedness in order to allow researchers to establish a minimum minimorum of parameters and to choose the most efficient combination.

The EEG obtained in the study in chapter 5 was analyzed for frontal alpha asymmetry, one of the many variables available in the abundant set of data. Frontal alpha asymmetry has been linked to motivational behavioral tendencies (approach and avoidance behavior) and positive and negative stimuli. It seems a logical step for sensory consumer science. Yet, in the EEG many more variables are registered and can be researched. Functional connectivity, event related potentials (ERPs) and power spectrum analysis arise for future research in sensory consumer science as they have been positively used in other fields (Imperatori, et al., 2015; Jacquin-Piques, et al., 2015; Tóth, et al., 2004).

It is important to note that there is currently a lack of standardized methods in food research to measure implicit neurophysiological responses to food. There is also no determination of the appropriate types of standards against which to standardize data when responses to food are measured. Emotion studies in the domain of psychology stressed the importance of the use of an appropriate baseline or control (Davidson & Irwin, 1999). The rise of implicit measures should also bring standardization in the methods and data processing for food stimuli including the entire scope of the food experience. Future research should further optimize, standardize and validate the implicit measures suitable for food research. Benchmarking these measures and comparing them with explicit measures can yield positive results in understanding the consumers' food experience. Interdisciplinary work may give inspiration for new methods. Applying these implicit measures on their own or combined with explicit measures and thoroughly evaluating them to reach standardized approaches, can help all future researchers in their work and additionally will make it more easy to compare results of different studies. This doctoral thesis has indicated that there are clear opportunities and gains, yet the new field of implicit measures in sensory science should be broadened by future research.

Products

Dark chocolate samples were used in the studies in chapter 3 and 4. Overall, studies applying explicit measures most often opted for products with high consumer acceptance levels, such as snack products and chocolate, as shown in the systematic review in chapter 2. These highly likable products are assumed to evoke more emotional conceptualizations (Jiang, King, & Prinyawiwatkul, 2014). In line with previous research, the studies in chapters 3 and 4 also opted for a product category with high consumer acceptance levels, dark chocolate. However, this might have influenced the emotional profiling, for example by overestimating the amount of emotional conceptualizations associated with the product.

Chapter 5 included very diverse taste stimuli, in specific solutions and drinks that were expected to elicit different hedonic responses, ranging from strongly liked to strongly disliked. As stated in chapter 2, implicit measures more frequently choose products with low consumer acceptance levels. Previous research suggested that implicit responses might be sensitive enough to detect differences in food products that are either very high or either very low in acceptance (Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017). Discriminating between food products which are similar in hedonic value or neutral in hedonic value (neither like nor dislike) by use of neurophysiological responses might be more challenging (Walsh, Duncan, Bell, O'Keefe, & Gallagher, 2017). Nevertheless, future research should look into the possibilities to discriminate between equally accepted products.

Blind sensory evaluation

All studies in this doctoral thesis used only blind sensory evaluation of the food products and thus leave out extrinsic quality cues, such as nutrition information, nutrition and health-related claims, ingredients, labels, brand name. As a result the participants had no knowledge of the composition of the chocolates (chapters 3 and 4), nor the solutions and drinks (chapter 5). This doctoral research opted for blind evaluations to avoid bias and to obtain a focus on the sensory attributes only. Expectations based on information cues could for example influence the evaluation of the products. Previous research showed an influence of previous experiences, information on the label, the appearance and package on the sensory and hedonic evaluation and drives sensory evaluation in the direction of expectations (Kähkönen & Tuorila, 1999; Norton, Fryer, & Parkinson, 2013; Schouteten, et al., 2015; Torres-Moreno, Tarrega, Torrescasana, & Blanch, 2012; Varela, Ares, Giménez, & Gámbaro, 2010).

However, these information cues are not left out in real life purchase situations. Even more so, consumers rely on these cues to make choices and discriminate between products and extrinsic cues such as brand, package, claims influence food choice and the sensory evaluation (Piqueras-Fiszman & Spence, 2015). As consumers' food choice is at least partially driven by these cues, food product developers can use these cues to differentiate a product from the competitors' alternatives. For future studies, the inclusion of information cues is suggested. Next to these information cues, other drivers of choice, for example economic drivers like price, should be included in future research to see if and when trade-offs like taste versus price are made. This better grasp of purchasing behavior will help to fully understand the consumers' food experience.

Laboratory context

All studies took place in a laboratory environment in order to standardize the testing and to control the environmental factors as much as possible. Yet, this controlled environment might lower the ecological validity. Although tests carried out in a (sensory) laboratory setting are easier to compare when taken place in different locations (e.g. different regions or countries) and on different occasions, this consumption context does not resemble actual food consumption. Despite the lower ecological validity, implicit measures especially need a controlled setting as they are technically more challenging than a questionnaire. Hence, laboratory environments rather than real-life settings are more suitable for implicit measurements (de Wijk, He, Mensink, Verhoeven, & de Graaf, 2014).

Although laboratory settings are more convenient for implicit measures, creating a more real-life setting within the laboratory is suggested. In order to approximate real-life consumption, one could opt to simulate an eating environment, by instructing participants to think about an imaginary consumption setting (Piqueras-Fiszman & Jaeger, 2014a, 2014b, 2014c), by using a written scenario (Dorado, et al., 2016) or setting up a real-life environment like a kitchen (Labbe, Ferrage, Rytz, Pace, & Martin, 2015), lounge setting (Bhumiratana, Adhikari, & Chambers, 2014) or a simulated restaurant or cafeteria setting (Dalenberg, et al., 2014; Gutjar, et al., 2015a). In order to create a new (real-life) reality within the laboratory setting, very recent advancements are made through use of an immersive or virtual context. This would allow the best of two worlds: the laboratory context under controlled circumstances versus the more realistic consumption context.

6.4 Implications for food companies

This doctoral dissertation looks at the wide field of measurements of consumers' food experience and comprises both the explicit and the implicit measures. The insights of this doctoral thesis are not only important for scientific goals, but are of value to professional food companies. Food companies, especially food product developers and marketing professionals, might value the insights to obtain a better understanding of the consumers' food experience.

For innovative food product development the consumers perspective or voice of the consumer is essential (De Pelsmaeker, 2016). Hence, consumer-driven food product development is considered as an important and interesting approach to lower the product failure rate (Costa & Jongen, 2006). In order to acquire successful food product development one needs to understand the complexity of consumers' food experience (Linnemann, Benner, Verkerk, & van Boekel, 2006; Sijtsema, Linnemann, Gaasbeek, Dagevos, & Jongen, 2002). As such the inclusion of emotional conceptualizations and implicit acceptance and food product-elicited emotions adds to the voice of the consumer and to consumer-driven food product development.

Recent changes force the food sector to innovate in order to stay in business (Sarkar & Costa, 2008). One of the these changes is the consumers' demand for higher product quality in terms of freshness, storage life, et cetera (van der Valk & Wynstra, 2005) and consumers' demand for healthier food products (Meiselman, 2013). In 2015, the main drivers for innovation are the consumers' expectations of pleasure and health (FoodDrinkEurope, 2016). The studies in part II of this dissertation provide insights for product development focusing on health expectations of consumers. Consumers are increasingly aware about the risks of high sugar intake and there is a more prominent role of low-calorie sweeteners in the market (Ghosh & Sudha, 2012; Goyal & Goyal, 2010). In attempts to address consumers' demands to reduce sugar intake and market competition, food companies need to examine consumers' acceptance of low-calorie sweeteners. Given the high priority of reducing sugar consumption, a better understanding of consumer's perceptions through both sensory and emotion research can contribute to underpin new ways to reduce sugar intakes and to brand and improve alternative sweeteners. Additionally, this understanding can be crucial for nutrition policy in order to develop strategies which target the promotion of healthy consumption behavior.

The non-verbal measurement of food-product-elicited emotions can also be of interest for export opportunities of food companies. Export orientation of food companies is seen as a determinant of innovation (Karantininis, Sauer, & Furtan, 2010). The emoji-based questionnaire can be used to benchmark products across different regions where translation might be an issue. This can serve as a base to determine which already existing product might be suitable for export or to adjust new products to cultural preferences before testing. Adding to this, marketers can similarly use the emoji-based questionnaire for testing marketing features like size, color, type of wrapping, name, shape, and so forth. Consequently, marketers can determine preferences across different regions or come up with a cultural framework for food products.

Nowadays, an emerging discipline is consumer-neuroscience and neuromarketing research. Consumer-neuroscience is an interdisciplinary field that combines psychology, neuroscience and economics to study how the brain is physiologically affected by advertising and marketing strategies (Khushaba, et al., 2013). It involves thus mainly branding and advertisement (Solnais, Andreu-Perez, Sánchez-Fernández, & Andréu-Abela, 2013), but the strength is that it may hit on subconscious biases that traditional research fail to uncover (Singer, 2004). Recently, major consumer brands have been using various neuromarketing techniques to obtain consumer insights. This doctoral research opens up the approach to study consumers' responses to tasted food products and stretches the interdisciplinary field to include sensory science. Bridging the knowledge gap between what is measured through explicit methods and what is measured through implicit methods is essential for food companies and therefore the information obtained through implicit measures can offer new insights in consumers' motivational tendencies and consequently enriching consumer-driven product development. Food companies looking for ways to understand underlying motivational behavior and consumer decision making might value the insight of this doctoral research. However, the application of implicit measures, more specifically neurophysiological measures, is new in sensory research, this research functions as a first approach to reveal the consumers' real drivers for acceptance of food products. Food developers and marketers may be prompted to consider measuring the consumers' food experience by including innovative approaches such as interdisciplinary implicit measures. The cross-over between different disciplines will drive innovation in food companies.

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Appendices

Appendix A: List of scale (a) 9-pioint hedonic liking scale (b) CATA scale (c) RATA (d) PrEmo (Chapter 1)

(a)

Please take a bite of sample 246 and indicate your overall opinion about this sample.

Dislike extremely	*Dislike very much*	*Dislike moderatly*	*Dislike slightly*	*Neither dislike nor like*	*Like slightly*	*Like moderately*	*Like very much*	*Like extremely*
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*

(b)

Please taste sample 246.
Please select the words which describe how you FEEL RIGHT NOW. Select all that apply.

☐ *Active*	☐ *Glad*	☐ *Pleasant*
☐ *Adventurous*	☐ *Good*	☐ *Polite*
☐ *Affectionate*	☐ *Good-natured*	☐ *Quiet*
☐ *Aggressive*	☐ *Guilty*	☐ *Satisfied*
☐ *Bored*	☐ *Happy*	☐ *Secure*
☐ *Calm*	☐ *Interested*	☐ *Steady*
☐ *Daring*	☐ *Joyful*	☐ *Tame*
☐ *Disgusted*	☐ *Loving*	☐ *Tender*
☐ *Eager*	☐ *Merry*	☐ *Understanding*
☐ *Energetic*	☐ *Mild*	☐ *Warm*
☐ *Enthusiastic*	☐ *Nostalgic*	☐ *Whole*

Note: EsSense Profile® ballot using check-all-that-apply response format (King & Meiselman, 2010)

(c)

Please taste sample 246.
Please select the words which describe how you FEEL RIGHT NOW. Select all that apply.

☐ *Active*	☐ *Glad*	☑ *Pleasant*
☐ *Adventurous*	☑ *Good*	☐ *Polite*
☐ *Affectionate*	☐ *Good-natured*	☐ *Quiet*
☐ *Aggressive*	☐ *Guilty*	☐ *Satisfied*
☐ *Bored*	☑ *Happy*	☐ *Secure*
☐ *Calm*	☐ *Interested*	☐ *Steady*
☐ *Daring*	☐ *Joyful*	☐ *Tame*
☐ *Disgusted*	☐ *Loving*	☐ *Tender*
☐ *Eager*	☐ *Merry*	☐ *Understanding*
☐ *Energetic*	☐ *Mild*	☐ *Warm*
☑ *Enthusiastic*	☐ *Nostalgic*	☐ *Whole*

Please rate the intensity of the applied emotional terms.

	Slightly				*Extremely*
Happy	*1*	*2*	*3*	*4*	*5*
Good	*1*	*2*	*3*	*4*	*5*
Pleasant	*1*	*2*	*3*	*4*	*5*
Enthusiastic	*1*	*2*	*3*	*4*	*5*

(d)

What do you feel about sample 246?

Note: PrEmo (Desmet, 2003)

Appendix B: Nutritional values, ingredient list of the examined chocolate products (Chapter 3)

	Regular	Low-calorie sweeteners	
Nutritional value per 100 g	**Chocolate + sugar**	**Chocolate + tagatose**	**Chocolate + stevia**
Energy	520 kcal/2166 kJ	457 kcal/1888 kJ	432 kcal/1808 kJ
Fats	30.9 g	35.1 g	34.8 g
- Of which saturated fats	19.3 g	21.4 g	21.9 g
Carbohydrates	50.5 g	47.1 g	18.7 g
- Of which sugar	46.9 g	0.3 g	3.2 g
- Of which polyols	0.0 g	3.6 g	8.7 g
Fibers	7.9 g	7.8 g	34.8 g
Proteins	5.5 g	5.5 g	5.3 g
Sodium	0.006 g	0.01 g	0.016 g
Ingredient list	cocoa mass, sugar, cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cocoa solids: minimum 50%. May contain milk, egg, gluten and nuts.	cocoa mass, sweetener (tagatose 45.3%), cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cacao solids: minimum 54%. Contains naturally occurring sugars. May contain traces of nuts and milk.	cocoa mass, alimentary fiber (dextrin, inulin, oligofructose), sweeteners (erythritol, steviol glycosides), cocoa butter, emulsifier: soy lecithin, natural vanilla flavor. Cacao solids: minimum 55%. Produced in a plant processing milk protein, wheat and nuts. Contains naturally occurring sugars.

Note: all values are expressed per 100 g of chocolate.

Appendix C: Nutritional values, ingredient list of the examined chocolate products (Chapter 4)

Nutritional value per 100g	Private-label	Private-label + bio-label	A-label	A-label + tagatose	A-label + stevia
Energy	520 kcal/ 2165 kJ	545 kcal/ 2275 kJ	535 kcal/ 2228 kJ	418 kcal/ 1728 kJ	458 kcal/ 1915 kJ
Fats	29 g	35 g	34 g	33.4 g	36.8 g
- Of which saturated fats	17 g	21 g	21.1 g	20.3 g	22.3 g
Carbohydrates	53 g	48 g	47.6 g	48 g	14 g
- Of which sugar	47 g	44 g	44.9 g	3 g	2.7 g
- Of which polyols	0.0 g	0.0 g	0.0 g	0 g	9.9 g
Fibers	10 g	8 g	7.9 g	8g	35 g
Proteins	6.5 g	6.5 g	5.1 g	5.6 g	5.7 g
Sodium	0.0 g	0.0 g	0.02g	0.01 g	0.21 g
Ingredient list	cocoa mass, sugar, lactose, cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cocoa solids: minimum 50%. May contain milk, egg, gluten and nuts.	cocoa mass, cane sugar, cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cocoa solids: minimum 55%. May contain milk, egg, gluten and nuts.	cocoa mass, sugar, cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cocoa solids: minimum 52%. May contain milk, egg, gluten and nuts.	cocoa mass, sweetener (tagatose 45%), cocoa butter, emulsifier (soy lecithin), natural flavor (vanilla). Cacao solids: minimum 54%. Contains naturally occurring sugars. May contain traces of nuts and milk.	cocoa mass, alimentary fiber (inulin), sweeteners (maltitol, steviol glycosides), fat reduced cocoa powder, emulsifier (soy lecithin), natural flavor. Cacao solids: minimum 52%. May contain traces of nuts and milk. Contains naturally occurring sugars.

Note: all values are expressed per 100 g of chocolate.

Appendix D: Correlations between mood, liking and emotional conceptualizations (Chapter 4)

Mood / EC	😊	😀	😄	😍	☺️	😌	😎	😏	😛	😁	😉
Liking	-0,012	0,002	0,190*	0,151	0,011	0,004	0,096	0,059	0,092	0,185*	0,163*
😊	0,472***	0,072	0,243**	0,205*	0,309***	0,176*	0,208*	0,194*	0,059	-0,045	0,234**
😀	0,098	0,408***	0,310***	0,074	0,187*	0,083	0,154	0,110	-0,029	0,104	0,203*
😄	0,127	0,179*	0,498***	0,341***	0,134	0,068	0,153	0,132	0,030	0,243**	0,183*
😍	0,168*	0,046	0,294***	0,53***	0,098	0,061	0,311***	0,148	0,183*	0,186*	0,188*
☺️	0,202**	0,117	0,146	0,049	0,475***	0,176*	0,086	0,137	0,312***	0,105	0,281**
😌	-0,021	0,013	0,031	0,033	0,277**	0,378***	0,097	0,173*	0,075	-0,030	0,150
😎	0,174*	0,130	0,123	0,223**	0,236**	0,310***	0,585***	0,445***	0,175*	0,260**	0,250**
😏	0,107	0,100	0,012	0,039	0,159	0,205*	0,399***	0,483***	0,109	0,149	0,148
😛	0,118	0,102	0,129	0,297***	0,332***	0,071	0,222**	0,172*	0,474***	0,209*	0,243**
😁	0,002	0,059	0,139	0,225***	0,060	0,152	0,236**	0,095	0,190*	0,486***	0,059
😉	0,077	0,144	0,128	0,095	0,168*	0,147	0,387***	0,309***	-0,045	0,232*	0,512***
😘	0,027	0,024	0,321***	0,316***	0,129	-0,053	0,109	-0,040	0,111	-0,020	0,219**
😜	0,138	0,084	0,259**	0,145	0,161	0,027	0,208*	0,066	0,162	0,121	0,183*
😂	0,116	0,197*	0,276**	0,317***	0,125	0,091	0,214*	0,186*	0,223**	0,194**	0,073
😐	-0,081	0,117	-0,174*	-0,056	-0,039	0,035	-0,062	-0,010	-0,073	-0,003	0,007
😑	0,035	0,038	-0,045	0,137	0,146	0,225**	0,056	0,132	-0,056	-0,029	0,050
😬	0,034	0,052	0,081	-0,012	-0,014	0,159	0,079	0,181*	0,053	0,454***	0,033
😴	0,051	-0,070	-0,089	-0,078	0,019	0,176	0,140	0,051	0,098	-0,046	0,031
😳	0,122	0,129	0,077	0,129	0,169	0,151	0,121	0,318***	0,177*	0,268**	0,189*
😝	-0,014	0,165*	0,108	0,042	0,063	0,185*	0,316***	0,157	0,011	0,319***	0,083
😱	0,084	0,106	0,137	0,246**	0,190*	0,114	0,234**	0,161	0,405***	0,262**	0,127
😕	0,045	0,102	-0,004	0,051	-0,030	0,023	-0,029	0,094	-0,043	0,026	-0,038
😖	0,087	-0,054	0,110	0,101	0,129	0,085	0,043	-0,076	0,099	-0,015	0,068
😒	0,054	-0,078	-0,070	0,149	-0,021	-0,007	-0,017	-0,050	-0,017	0,146	0,037
😫	-0,049	-0,028	-0,001	0,042	0,024	0,145	0,034	0,024	0,104	0,058	0,004
😔	0,017	0,107	0,168*	0,125	0,062	-0,042	0,060	0,109	0,199*	0,033	-0,008
😣	0,049	0,073	0,106	-0,012	0,118	-0,075	-0,076	-0,032	-0,028	-0,044	-0,089
😩	0,052	0,020	-0,017	-0,005	-0,053	-0,072	0,215**	-0,036	0,012	-0,014	0,147
😞	-0,074	-0,029	0,122	0,006	0,069	-0,035	0,156	-0,003	0,065	0,027	-0,027
😠	-0,033	0,087	-0,023	-0,010	-0,054	-0,072	0,029	0,139	0,007	-0,017	0,039
😓	0,157	-0,070	-0,040	-0,009	-0,020	-0,037	-0,018	-0,011	0,034	0,156	0,096
😢	0,059	-0,065	-0,040	-0,015	-0,024	-0,036	0,227**	-0,015	0,018	0,00	0,209*
😭	0,084	0,106	0,137	0,246**	0,190*	0,114	0,234**	0,161	0,405***	0,262**	0,127

Appendix D *(Continued)*

Mood / EC	😘	😜	😂	😐	😑	😬	😴	😳	😝	😱	😕
Liking	0,097	0,079	0,065	-0,054	-0,093	0,080	-0,047	-0,027	-0,054	-0,098	-0,030
😊	0,139	0,186*	-0,001	-0,070	-0,068	-0,029	0,113	-0,017	0,052	-0,103	0,008
😀	0,017	0,243	-0,108	-0,074	-0,054	0,001	0,119	-0,056	0,158	-0,053	-0,132
😄	0,014	0,254**	0,055	-0,093	-0,085	0,009	0,063	-0,032	0,277**	-0,053	0,040
😍	0,207*	0,186*	0,189*	-0,102	-0,049	0,080	0,025	-0,011	0,213**	-0,033	0,048
☺️	0,157	0,176**	0,033	0,060	-0,017	0,059	-0,073	0,013	0,035	-0,063	0,015
😌	0,019	0,053	-0,087	0,145	-0,02	0,057	0,155	-0,052	-0,051	0,028	-0,012
😎	-0,013	0,236	0,070	0,114	-0,048	0,095	0,210*	-0,017	0,336***	-0,039	0,027
😏	0,029	0,098	0,014	0,039	-0,038	0,078	0,137	-0,026	0,2*	-0,045	0,012
😛	-0,013	0,317***	0,202**	0,012	-0,040	0,185*	0,023	0,006	0,184*	-0,021	0,111
😁	0,010	0,171*	0,111	-0,078	0,019	0,037	0,134	0,010	0,278**	-0,016	0,034
😉	0,091	0,235**	0,133	0,075	0,006	0,084	0,254**	-0,019	0,082	-0,042	0,023
😘	0,664***	0,115	0,007	-0,009	-0,010	0,024	0,026	0,027	0,047	0,000	-0,002
😜	-0,010	0,638***	0,064	0,017	0,009	0,130	-0,033	0,005	0,138	-0,016	0,070
😂	0,526***	0,134	0,286***	0,035	0,055	0,300***	0,018	0,117	0,224**	0,054	0,215**
😐	-0,034	-0,062	0,085	0,148	0,127	0,022	0,022	-0,013	-0,044	0,050	-0,030
😑	0,071	0,050	-0,034	0,218**	0,298***	0,068	0,156	-0,025	0,023	-0,045	0,067
😬	-0,013	0,164*	0,186*	0,085	0,046	0,173*	0,077	0,002	0,369***	-0,016	0,108
😴	-0,005	-0,062	-0,022	0,057	0,013	-0,008	0,417***	0,007	0,007	-0,013	0,042
😳	-0,024	0,232**	0,347***	-0,021	0,003	0,427***	-0,077	-0,005	0,208*	0,071	0,198*
😝	0,052	0,317***	0,107	0,019	0,009	0,151	0,292***	0,011	0,494***	-0,012	0,029
😱	0,433**	0,240**	0,37***	0,170*	0,184*	0,441***	0,149	0,31***	0,291***	0,165*	0,281***
😕	-0,096	0,135	0,162	0,103	0,056	0,079	-0,100	-0,043	-0,018	0,027	0,156
😖	0,032	0,159	-0,052	0,035	0,076	0,030	0,161	0,180*	0,210*	-0,027	0,101
😒	0,146	0,099	0,288***	0,053	0,026	0,221**	-0,037	0,221**	-0,003	-0,015	0,036
😫	0,120	0,046	0,097	0,027	0,424***	0,122	0,189*	0,09	0,074	0,042	0,070
😔	0,005	0,092	0,087	0,017	0,054	0,223**	-0,010	0,015	0,122	-0,009	0,058
😣	-0,005	-0,060	-0,020	0,038	-0,025	-0,007	-0,052	0,007	-0,022	-0,012	-0,024
😩	0,034	0,109	0,115	0,134	0,063	0,033	0,135	0,033	0,060	0,004	0,005
😞	0,085	0,013	0,063	0,155	0,179*	0,085	0,127	0,067	0,167*	0,026	0,043
😠	0,029	-0,031	0,102	0,087	-0,007	0,027	0,175*	0,029	0,004	0,329***	0,001
😓	0,049	-0,002	0,400***	-0,010	0,009	0,049	0,071	0,041	0,023	0,013	0,021
😢	0,031	0,296***	0,019	0,178*	0,002	0,030	-0,025	0,027	0,012	0,007	0,010
😭	0,433***	0,240**	0,370***	0,170*	0,184*	0,441***	0,149	0,31***	0,291***	0,165*	0,281*

Appendix D *(Continued)*

Mood / EC	😖	😒	😫	😔	😣	😩	😞	😠	😓	😢	😭
Liking	-0,015	-0,091	-0,052	-0,044	-0,045	-0,056	-0,110	0,034	0,028	0,069	-0,012
😊	-0,089	-0,104	-0,098	-0,110	-0,111	-0,102	-0,037	-0,071	-0,020	-0,100	-0,074
😀	-0,030	-0,083	-0,022	-0,126	-0,018	-0,048	-0,030	-0,014	0,006	-0,015	-0,016
😄	-0,028	-0,040	-0,049	0,094	0,001	-0,052	-0,065	0,029	-0,014	-0,011	-0,034
😍	-0,023	-0,045	-0,028	0,184*	-0,009	-0,031	-0,034	-0,003	0,017	0,000	-0,016
☺️	-0,050	-0,032	-0,034	0,026	-0,013	0,017	0,074	-0,030	0,080	-0,016	-0,040
😌	-0,037	0,078	-0,053	-0,064	-0,080	-0,080	-0,102	0,117	0,007	-0,043	-0,054
😎	-0,028	0,009	-0,034	-0,061	0,005	-0,037	-0,043	0,089	0,010	0,003	-0,021
😏	-0,036	-0,048	-0,041	-0,033	0,039	-0,044	-0,034	-0,021	-0,009	-0,059	-0,029
😛	-0,009	-0,026	-0,014	-0,036	-0,023	-0,018	-0,013	0,020	0,051	-0,020	-0,002
😁	-0,004	-0,007	-0,009	0,119	0,085	-0,013	0,025	0,026	0,058	-0,014	0,002
😉	-0,031	-0,058	-0,037	-0,066	-0,046	-0,040	-0,047	-0,011	0,098	0,026	-0,023
😘	0,012	0,005	0,008	-0,007	0,000	0,004	0,019	0,046	0,084	0,011	0,017
😜	-0,007	-0,006	-0,011	-0,029	0,021	-0,014	0,026	0,016	0,041	0,122	-0,002
😂	0,082	0,093	0,073	0,061	0,060	0,064	0,124	0,170**	0,277**	0,104	0,087
😐	0,098	0,062	0,095	-0,038	0,062	0,133	0,091	0,100	-0,060	0,037	0,080
😑	-0,035	-0,016	0,047	0,043	-0,050	-0,044	0,065	-0,019	-0,004	-0,058	-0,028
😬	-0,008	0,100	-0,012	-0,028	0,105	-0,014	-0,012	0,201*	0,032	-0,017	-0,003
😴	-0,004	-0,016	-0,008	-0,024	-0,015	-0,011	-0,006	0,019	0,043	-0,011	0,001
😳	-0,014	0,047	0,070	0,022	-0,024	-0,020	0,026	0,002	0,017	-0,025	-0,009
😝	-0,001	-0,013	0,046	-0,023	0,146	-0,009	-0,002	0,025	0,054	-0,008	0,004
😱	0,228**	0,273**	0,21*	0,197*	0,183*	0,188*	0,346***	0,442***	0,705***	0,300***	0,236**
😕	0,028	-0,066	0,205*	0,014	-0,003	0,082	0,181*	-0,041	-0,033	-0,031	0,040
😖	-0,021	0,209*	-0,024	0,150	-0,02	0,064	0,187*	0,174*	0,003	0,061	-0,016
😒	-0,002	0,348***	0,088	0,110	0,153	-0,011	0,049	0,291***	0,067	0,160	0,004
😫	0,063	0,209*	0,057	0,047	0,047	0,049	0,438***	0,131	0,214**	0,081	0,067
😔	0,002	-0,010	-0,003	0,197*	-0,010	-0,007	0,003	0,030	0,062	-0,004	0,007
😣	-0,003	-0,015	-0,007	0,185	-0,014	0,280**	0,346***	0,019	0,043	-0,011	0,001
😩	0,017	0,011	0,012	-0,002	0,005	0,008	0,026	0,054	0,098	0,177*	0,022
😞	0,044	0,046	0,038	0,026	0,029	0,032	0,161	0,101	0,168*	0,054	0,048
😠	0,456***	0,008	0,010	0,128	0,365***	0,374***	0,021	0,048	0,088	0,306***	0,473***
😓	0,025	0,025	0,021	0,012	0,015	0,017	0,039	0,062	0,106	0,030	0,029
😢	0,016	0,014	0,013	0,004	0,008	0,010	0,111	0,042	0,073	0,322***	0,018
😭	0,228*	0,273*	0,210*	0,197*	0,183*	0,188*	0,346***	0,442***	0,705***	0,300***	0,236**

Curriculum Vitae

Sofie Lagast graduated in 2009 with a Master degree in Clinical and Health Psychology at the Catholic University of Leuven. During one additional year she specialized in neuroscience and health psychology by obtaining different credits at the Catholic University of Leuven. After working as a clinical psychologist, she joined the UGent SensoLab at the Department of Agricultural Economics of Ghent University as a doctoral researcher in 2013. Her research interest and expertise are related to consumers' food experience, sensory analysis of food products, neurophysiology and motivational behavior. Sofie Lagast is author and co-author of various scientific publications in peer-reviewed journals and has presented her results at several international conferences.

Personal information

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Education

Nov 2013 - Current — PhD student at Ghent University, Belgium

Faculty of Bioscience Engineering

Department Agricultural Economics

Division Agri-Food Marketing and Chain Management, UGent SensoLab

Jan 2013 - Jun 2017 — Doctoral Schools at Ghent University, Belgium
Specialist courses at the Faculty of Bioscience Engineering

- Sensory analysis
- Consumer behavior and marketing of agri-food products
- Food and nutrition epidemiology
- Functional Food
- Introduction to Business management

Specialist course at the Faculty of Economics and Business Administration

- Research methodes in marketing: market research

Transferable skills: Communication, Leadership & Personal efficiency courses at Doctoral Schools

- Advanced Academic English: Conference skills – Presentations skills in English
- Personal effectiveness

Transferable skills: Reseach & Valorisation course at Wagening Academy, Wageningen University, The Netherlands

- Course 'to buy or not to buy (healthy)'

Sept 2009 - Jun 2010 — Credits at Catholic University Leuven, Belgium
Credits at the Faculty of Medicine

- Advanced system and cognitive neurosciences
- Hot topics in system and cognitive neurosciences

Credits at the Faculty of Kinesiology and Rehabilitation Sciences

- Psychology of the temporary and permanent disabled
- Psychology of movement

Credits at the Faculty of Psychology and Education sciences

- Group dynamics, part 1
- Group dynamics, part 2

Credits at the Faculty of Social Sciences

- Media and health care

Sep 2007 - Jun 2009 Master in Psychology, Clinical and Health Psychology. Cum laude
Catholic University of Leuven, Belgium
Optional subjects:

- Advanced topics in the behavioral neurosciences
- Cases in clinical neuropsychology
- Topics in child neurology
- Questions in neurosciences

Master thesis: “The effect of dorsal hippocampal and cerebellar lesions during visual spatial learning in mice”.
Departement Biological Psychology (Promotors Professor dr. D'hooge and dr. Ilse Gantois)

Sep 2004 - Jun 2007 Bachelor in Psychology. Cum laude
Catholic University of Leuven, Belgium

Publications

International Peer-Reviewed Articles in Journals included in the ISI Web of Science

Lagast, S., Gellynck, X., Schouteten, J. J., De Herdt, V., & De Steur, H. (2017). Consumers’ emotions elicited by food: a systematic review of explicit and implicit methods. *Trends in Food Science & Technology, 69,* 172-189.

Lagast, S., De Steur, H., Schouteten, J. J., & Gellynck, X. (in press). A comparison of two low-calorie sweeteners and sugar in dark chocolate on sensory attributes and emotional conceptualisations. *International Journal of Food Sciences and Nutrition*. Advanced online publication. http://dx.doi.org/10.1080/09637486.2017.1362689.

Schouteten, J., De Steur, H., **Lagast, S.**, De Pelsmaeker, S., & Gellynck, X. (2017). Emotional and sensory profiling by children and teenagers : a case study of the check-all-that-apply method on biscuits. *Journal of Sensory Studies*, 32 (1).

Schouteten, J., De Steur, H., De Pelsmaeker, S., **Lagast, S.**, Juvinal, J., De Bourdeaudhuij, I., Verbeke, W., et al. (2016). Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. *Food Quality and Preference, 52,* 27–31.

Schouteten, J., De Steur, H., De Pelsmaeker, S., **Lagast, S.,** De Bourdeaudhuij, I., & Gellynck, X. (2015). An integrated method for the emotional conceptualization and sensory characterization of food products: the EmoSensory® wheel. *Food Research International*, *78*, 96–107.

Schouteten, J., De Steur, H., De Pelsmaeker, S., **Lagast, S.,** De Bourdeaudhuij, I., & Gellynck, X. (2015). Impact of health labels on flavor perception and emotional profiling: a consumer study on cheese. *Nutrients*, *7* (12), 10251–10268.

International Peer-Reviewed Articles in Journals included in the ISI Web of Science: in review process

Lagast, S., Schouteten, J.J., Gellynck, X., De Steur, H.(2017). Consumers' emotional conceptualizations elicited by tasting dark chocolate using a non-verbal emoji-based questionnaire. Under review in *Appetite*.

Lagast, S., De Steur, H., Schouteten, J.J., Gadeyne, S., Hödl, S., Staljanssens, W., Vonck, K., Boon, P., Gellynck, X., De Herdt, V. (2017). Neurophysiological responses in sensory evaluation: an experiment on accepted and non-accepted solutions and drinks. Under review in *Behavioural Brain Research*.

Schouteten, J.J., De Pelsmaeker, S., Juvinal, J., **Lagast, S.**, Dewettinck, K., Gellynck, X. (2017). Influence of sensory attributes on consumers' emotions and hedonic liking of chocolate. Under review in *British Food Journal*.

Schouteten, J.J., **Lagast, S.**, Gellynck, X., De Steur, H. (2017). Emoji as a tool for measuring children's emotions when tasting food. Under review in *Food Quality and Preference*.

Book Chapters

Schouteten, J., De Steur, H., De Pelsmaeker, S., **Lagast, S.**, Gellynck, X., & De Bourdeaudhuij, I. (2017). Emotional and Sensory Evaluation of Cheese: The Effect of Health Labels. In R. R. Watson, R. J. Collier, & V. R. Preedy (Eds.), *Dairy in Human Health and Disease Across the Lifespan* (1st ed., pp. 295–311). London, UK: Academic Press.

Conferences contributions

Lagast, S., De Steur, H., Schouteten, J.J., Gadeyne, S., Hödl, S., Staljanssens, W., Boon, P., Gellynck, X., De Herdt, V. (2017). Implicit measurement of preference and emotion in universal and personally accepted and non-accepted drinks. *Pangborn Sensory Science, 12th Symposium, Abstracts*. Presented at the 12th Pangborn Sensory Science symposium.

Lagast, S., De Pelsmaeker, S., De Steur, H., Vandenhaute, H., Junival, J., Schouteten J.J., Gellynck, X. A conjoint study with tasting condition on dark chocolate: effect of flavour, portion size and sugar reduction claim on stated preference. Sensory and Consumer Research, 7th European conference, Abstracts. Presented at the 7th European conference on Sensory and Consumer Research (EuroSense 2016).

Schouteten, J., De Steur, H., **Lagast, S.,** De Pelsmaeker, S., Gellynck, X., & De Bourdeaudhuij, I. (2016). The effect of the location context on the EmoSensory® evaluation of yogurt products under blind, expected and informed conditions. Sensory and Consumer Research, 7th European conference, Abstracts. Presented at the 7th European conference on Sensory and Consumer Research (EuroSense 2016).

Schouteten, J., De Steur, H., **Lagast, S.,** Gellynck, X., De Bourdeaudhuij, I., Bredie, W. lP, & Perez-Cueto, F. J. (2016). Validating the EmoSensory® Wheel: comparison with traditional questionnaire format, between scaling formats and between countries. Sensory and Consumer Research, 7th European conference, Abstracts. Presented at the 7th European conference on Sensory and Consumer Research (EuroSense 2016).

Lagast, S., De Pelsmaeker, S., Schouteten, J., & Gellynck, X. (2015). Local food products in health care facilities: elderly sensory acceptance of a local food menu. *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

De Pelsmaeker, S., Schouteten, J., **Lagast, S.,** Dewettinck, K., & Gellynck, X. (2015). Tasting or non-tasting in conjoint analysis: is taste the key driver for purchase intent of consumers? *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

Schouteten, J., De Steur, H., De Pelsmaeker, S., **Lagast, S.,** De Bourdeaudhuij, I., & Gellynck, X. (2015). Effect of health labelling on expected and actual taste perception of cheese. *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

Lagast, S., De Steur, H., Schouteten, J., De Pelsmaeker, S., & Gellynck, X. (2015). Emotional connotations of consumers in blind sensory evaluation of chocolates with normal and alternative sweeteners. *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

Schouteten, J., De Steur, H., **Lagast, S.,** De Pelsmaeker, S., & Gellynck, X. (2015). Linking emotions and sensory attributes of traditional food products: an application of the CATA approach in a study on children. *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

Schouteten, J., Vella, A., De Clercq, N., Van Durme, J., **Lagast, S.,** De Pelsmaeker, S., Dewettinck, K., et al. (2015). Linking instrumental, sensory and emotional evaluation of flavoured chocolates. *Pangborn Sensory Science, 11th Symposium, Abstracts*. Presented at the 11th Pangborn Sensory Science symposium.

Schouteten, J., De Pelsmaeker, S., **Lagast, S.,** & Gellynck, X. (2014). Sensory evaluation of fresh, canned and frozen French beans by children. *SenseAsia 2014, Abstracts*. Presented at the SenseAsia 2014: the Asian Sensory and Consumer Research Symposium.

Lagast, S., Schouteten, J., De Pelsmaeker, S., & Gellynck, X. (2014). Sensory differences between low-fat and regular yogurt measured by instrumental analyses and consumer evaluation. *Food Structure and Functionality Forum Symposium, Abstracts*. Presented at the Food Structure and Functionality Forum Symposium: From molecules to functionality.

Schouteten, J., De Pelsmaeker, S., **Lagast,** S., & Gellynck, X. (2014). Can emotions deliver additional information on the informed liking of flavoured milk by children? *SenseAsia 2014, Abstracts*. Presented at the SenseAsia 2014: the Asian Sensory and Consumer Research Symposium.

Lagast, S., Schouteten, J., De Pelsmaeker, S., & Gellynck, X. (2014). Relation between sensory characteristics and consumer preference for traditional Belgian cheeses. *SenseAsia 2014, Abstracts*. Presented at the SenseAsia 2014: the Asian Sensory and Consumer Research Symposium.

Scientific presentations and workshops at events

Lagast, S. (2017). Sensorische analyse van chocolade. *Chocolade smaakt… naar meer, Seminar.* Presented at Faculty of Bioscience Engineering, Ghent University, Belgium.

Lagast, S. (2017). Theoretical and Practical Session of sensory analysis. *Chocolate and Cocoa Processing 2017, Seminar.* Presented at Faculty of Bioscience Engineering, Ghent University, Belgium.

Lagast, S. (2016). Sensory perception and the brain. *MOM4Y 2016 Breinwijzer vzw, Seminar.* Presented at Ghent University, Belgium.

Lagast, S. (2015). Workshop EEG measurement during sensory evaluation. *IBrain Festival 2015 Breinwijzer vzw, Workshop.* Presented at Ghent, Belgium.

Lagast, S. (2014). Link between sensory analysis and psychophysiology. *IntraFood 2014, Seminar.* Presented at Expo Kortijk, Belgium.

Lagast, S. (2014). Mobile EEG measurement during sensory evaluation. *Year Fair Ghent 2014, Workshop.* Presented at Flanders Expo Ghent, Belgium.

Educational involvement

2015 - 2017	Tutor of group work of the course Sensory Analysis
2015 - 2016	Tutor of group work of the course Consumer Behavior and Marketing of Agri-food Products:
2015 - 2016	Supervision of Master thesis students
	Vandenhaute, H. (2016). De invloed van claims omtrent suikerreductie, portiegrootte en smaak op preferentie en aankoopgedrag van donkere chocolade. Thesis to obtain the degree of M.Sc. in General Economics. Ghent University.
	Nys, S. (2015). Invloed van attitudes, emoties, sensorische eigenschappen op de smaakvoorkeur van het streekproduct speculoos. Een vergelijkende casestudie tussen kinderen en volwassenen. Thesis to obtain the degree of M.Sc. in Bioscience Engineering. Ghent University.
2015 - 2016	Supervision Bachelor thesis students
	Otte, V., Peters, B., Vanbesien, S., Vanoverberghe, H. (2016). Food for your brain: neuromarketing in de voedingsindustrie. Thesis to obtain the degree of B.Sc. in Bioscience Engineering. Ghent University.

Scientific support in projects

Jan 2016 – Feb 2017	Horizon 2020 Proposal BG 08 2017 SEAFOOD^{TOMORROW}
Jun 2014 – Oct 2014	Leader project: Economisch valoriseren van kwaliteitsvolle streekproducten en streekkarakteristieken in de Vlaamse Ardennen
Nov 2013 – Jun 2015	PDPO Vlaanderen (Plattelandsontwikkeling): As 3 gebiedsgerichte werking – project 'Smaakbeleving als hefboom voor marktinnovatie'
Nov 2013 – Sept 2015	Leader MLS – project 'Crowdsourcing en innovatie voor KMO's en detailhandel'

Professional Memberships

Neuromarketing Science & Business Association (NMSBA)