Development of new child-friendly methods to measure food-evoked emotions holistically

Noelia da Quinta González

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Director:

Iñigo Martinez de Marañón

Everyone knows what an emotion is,

until one is asked to give a definition.

Then, it seems, no one knows.

Beverley Fehr and James A. Russell

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En primer lugar, quisiera agradecer a Gobierno Vasco la oportunidad que me ha brindado, sin cuya financiación este doctorado no habría sido posible. Al mismo tiempo, estoy agradecida a la Universidad del País Vasco (UPV/EHU) y, en especial a Patxi, por guiarme en este proceso. Además, estoy especialmente agradecida a AZTI por permitir que desarrollase mi investigación en sus instalaciones, consiguiendo que me sintiera como una investigadora más.

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Eskerrik asko

RESUMEN

Las preferencias alimentarias de la población infantil se han evaluado tradicionalmente con la medida de la aceptabilidad y la preferencia. Sin embargo, diversos autores afirman que la aceptabilidad no es un indicador fiable que permita predecir las elecciones alimentarias en la vida real, mientras que se considera que las emociones contribuyen al entendimiento de las preferencias y elecciones alimentarias.

En la actualidad, existe una diversidad de teorías basadas en el conocimiento fisiológico, psicológico y neurocientífico que intentan explicar qué son las emociones. Entre ellas, destacan las teorías de las emociones básicas que consideran a las emociones como comportamientos innatos, las teorías dimensionales que describen a las emociones como conceptos variables en una o varias dimensiones y las teorías que consideran a las emociones como procesos de evaluación cognitiva. A pesar de las diferencias existentes entre ellas, todas contemplan que las emociones tienen un carácter multicomponente.

En los últimos años, se ha creado una base teórica que describe los tres tipos de metodologías capaces de medir los distintos componentes o aspectos de las emociones. En primer lugar, destacan los métodos cognitivos. Estas metodologías requieren un procesado cognitivo y una reflexión por parte de la persona en estudio y, por ello, son capaces de acceder al componente consciente de las emociones. Entre ellas, destacan los cuestionarios de auto-respuesta o las metodologías cualitativas tales como los grupos de discusión o las entrevistas personales. En segundo lugar, los métodos comportamentales (o conductuales) permiten asociar los movimientos faciales, corporales o cambios vocales con una respuesta emocional. Este tipo de señales emocionales son consideradas en esencia como respuestas inconscientes del comportamiento, pero la capacidad de control de dichos movimientos hace

que también puedan ser consideradas como medidas del inherente consciente de las emociones. En tercer lugar, los métodos fisiológicos evalúan cambios en la actividad del sistema nervioso, siendo por ello considerados como respuesta puramente inconscientes e involuntarias. Existen métodos muy variados en este sentido que examinan desde la actividad cerebral mediante sofisticados métodos de neuroimagen hasta la respuesta cardiaca o térmica. En este sentido, se considera que para obtener una respuesta emocional holística se deben aplicar diversas metodologías que evalúen cada uno de los componentes de las emociones.

Por otro lado, la elección de la metodología a aplicar en estudios con población infantil es de especial interés, ya que, debe estar adaptada al nivel de desarrollo cognitivo, físico y social de dicha población. Por ello, cuando se realizan estudios con población infantil, las personas investigadoras están obligadas a reconsiderar las metodologías existentes hasta el momento o a desarrollar otras nuevas que cumplan estos requisitos.

Esta disertación tuvo por objetivo el desarrollo de nuevas metodologías adaptadas a la población infantil de edad escolar para la medida holística de las emociones inducidas por los alimentos (a nivel cognitivo, comportamental y fisiológico). Para cumplir este objetivo se tomaron numerosas consideraciones metodológicas que permitieron solventar las limitaciones que frecuentemente se asocian a cada tipo de metodología.

En primer lugar, se diseñó una nueva metodología cognitiva para evaluar el componente consciente de las emociones. En este sentido, tradicionalmente se han empleado cuestionarios verbales. No obstante, las limitaciones que presentan los cuestionarios basados en el uso de palabras han sido descritas en numerosas ocasiones por otros autores. Entre estas limitaciones destacan la imposibilidad de uso con grupos poblacionales con una capacidad limitada de lectura o la necesidad de un alto esfuerzo cognitivo para su evaluación.

Por ello, para evaluar el inherente cognitivo de las emociones, en esta disertación se diseñó una herramienta gráfica basada en el uso de emoji. Estos iconos han sido utilizados con anterioridad en estudios centrados en población adulta, preadolescentes y población infantil. No obstante, las publicaciones científicas en este ámbito han destacado que el diseño gráfico de los emoji no retrata de forma unánime un estado emocional, pudiendo ser interpretado de diversas maneras en función de aspectos como la edad o el género de la persona evaluadora.

Por ello, ante la falta de bibliografía científica centrada en la población infantil de edad escolar, inicialmente, se evaluó el significado dimensional (en términos de valencia y activación) y semántico de emoji faciales, así como la influencia del contexto alimentario, la edad y el género en dicha percepción. Para ello, tras una selección inicial, se caracterizó un grupo de 30 emoji. Los resultados obtenidos mostraron que, de acuerdo con otros estudios anteriores, aspectos como la edad o el género de la población infantil de edad escolar influyen en la interpretación de los emoji faciales. Este estudio inicial también mostró por primera vez que la interpretación de los emoji se ve influenciada por el contexto de evaluación. Posteriormente, considerando la influencia que tiene el contexto alimentario en la interpretación de los emoji, se identificó un grupo de estos iconos con especificidad por diversos contextos alimentarios balanceados en términos de aceptabilidad. De este modo y tras eliminar emoji con usos redundantes, se obtuvo la herramienta basada en emoji que se había planteado como objetivo en esta disertación.

Posteriormente, la aplicabilidad de esta herramienta se evaluó en términos de capacidad de discriminar entre muestras y se determinó la influencia de diversos aspectos metodológicos en dicha aplicabilidad (tipo de estímulo, categoría de productos a evaluar y el rango de aceptabilidad de los mismos). Para ello, se desarrollaron dos estudios en los que se emplearon dichos emoji para medir la respuesta emocional inducida por nombres de alimentos, imágenes y alimentos reales. Se siguió este desarrollo metodológico para hacer que el estudio de validación fuese lo más completo posible, ya que, tal y como habían indicado otros autores con anterioridad, el modo en que se evocan los alimentos influye decisivamente en el comportamiento de las personas consumidoras. Los resultados de dichos estudios mostraron que la selección de emoji faciales con especificidad por el ámbito alimentarios tiene una amplia aplicabilidad en estudios con población infantil de edad escolar. Dichos emoji fueron capaces de discriminar alimentos inducidos como nombres y productos reales, teniendo una aplicabilidad limitada en el caso de las imágenes. Del mismo modo, los emoji mostraron capacidad discriminante en situaciones que se habían descrito como limitantes por otros autores (entre productos de una misma categoría y entre alimentos con equivalente valoración de aceptabilidad). Por primera vez, estos estudios pusieron de manifiesto que la activación emocional inducida por los alimentos en evaluación también puede ser un factor que limite la aplicabilidad de los emoji.

De entre las medidas comportamentales que pueden llevarse a cabo para estudiar la respuesta emocional de una persona, se decidió estudiar el cambio en la expresión facial mediante la técnica de codificación automática, por ser la principal fuente de información no verbal. No obstante, esta metodología presenta una serie de inconvenientes, tales como: (i) la falta de información sobre la validez de los resultados obtenidos con esta metodología en entornos reales, (ii) la falta de información del contexto en el que se realiza la medida, (iii) el propósito social de las expresiones faciales en lugar de aportar información emocional y (iv) la alteración de la expresión facial durante el consumo y procesado oral de alimentos debido al movimiento de músculos faciales. Por otro lado, la respuesta de la sudoración de la piel fue seleccionada como método de evaluación fisiológica por ser el tradicionalmente empleado para este fin en investigación científica. A pesar de su uso habitual, esa medida fisiológica también presenta limitaciones a su uso, tales como, la presencia de diferencias individuales entre personas.

Una vez identificadas las metodologías de partida, ante la escasez de información disponible sobre la capacidad de reconocimiento de la expresión facial de los softwares destinados a este fin en entornos realistas, se estudió la aplicabilidad del software FaceReader V8.0 en la codificación de la expresión facial en entornos alimentarios y con población infantil. Los resultados mostraron que dicha metodología tuvo una capacidad de reconocimiento aceptable de las expresiones faciales mostradas por la población infantil durante la observación de estímulos alimentarios, especialmente aquellos que inducen una respuesta emocional negativa, siendo mayor en el caso de alimentos reales que en imágenes.

Considerando estos resultados, posteriormente se diseñó un protocolo experimental que permitió codificar la expresión facial de las personas participantes y monitorizar conjuntamente sus niveles de sudoración de la piel. Dicha metodología fue diseñada para ser aplicada durante la evaluación sensorial de alimentos reales, tanto líquidos como sólidos, en un amplio espectro de experiencias sensoriales, tales como la observación, el olfateo, la manipulación y el consumo de los mismos. Durante la etapa de desarrollo metodológico hubo especial interés en diseñar un procedimiento que solventase las limitaciones que son frecuentemente asociadas a ambas metodologías. Los resultados obtenidos mostraron que la combinación de ambas metodologías es capaz de discriminar la respuesta emocional inducida tanto por alimentos líquidos como sólidos, incluso cuando inducen un grado equivalente de aceptabilidad, en las distintas fases de evaluación. La metodología combinada diseñada en esta disertación fue capaz de examinar la evolución en el tiempo de dicha respuesta emocional, pudiendo estudiar así tanto el componente inconsciente como consciente de las emociones.

SUMMARY

Children's food preferences have been traditionally evaluated with hedonic methods based on the measure of liking and preference. However, some authors reported that liking is not a strong predictor for food choice in real life environments, while the measurement of emotions could contribute the understanding of preferences and food choices. Since emotions have a multicomponent character, methodologies that measure each component of the emotion are necessary to reach an holistic perspective.

The election of the methodology to be used in child-centred studies is of special importance, since it should be adapted to their cognitive, physical, and social stage of development, what force researchers to reconsider the existing methodologies or to develop new ones.

This dissertation aimed to design new methodologies suitable for schoolchildren to measure food-evoked emotions holistically, i.e., at a cognitive, behavioural, and physiological level. To achieve this goal, several considerations were taken to overcome the limitations that characterise each methodology.

To evaluate the cognitive inherent of the emotion, an emoji-based tool was designed. Firstly, the perception that schoolchildren have on the dimensional (i.e., valence and arousal) and semantic meaning of facial emoji was evaluated, as well as the effect of a food-related context, age, and gender on that perception. On this regard, a group of 30 facial emoji were examined and characterised. Afterwards, facial emoji with specificity for a wide selection of food contexts balanced in pleasantness were identified from the initial list of emoji and were set as the emoji-based tool to be used in this dissertation. The applicability of this method was then validated in two studies in which the emotional response elicited by food names, food images and real food samples

was measured with the emoji. The applicability of the emoji-based tool was measured through the ability to discriminate among samples.

To deepen into de physiological and the behavioural component of the emotions, a methodology that combined the codification of facial expressions and the measure of the skin conductance response was designed. The methodology used was designed to be applied during the sensory evaluation of real food samples, which could be either liquid or solid, during their observation, olfaction, manipulation, and consumption. At this step, efforts were made and a new experimental protocol was designed to overcome the limitations traditionally associated with the measure of skin conductance response (i.e., the existence of individual differences) and with facial coding, such as: (i) lack of information about the validity of data in real settings, (ii) lack of context information during the measurement, (iii) the social purpose of facial expressions rather than emotional connotation, and (iv) the alteration of the facial expressions during mouth movements associated to the consumption and oral processing of foods.

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ABBREVIATIONS

º	Degrees	**Hz**	Hertzs
%	Percentage	**IDDSI**	International Dysphagia Diet Standardisation Initiative
ANOVA	Analysis of Variance	**n.s.**	Not significant
AU	Action Unit	**ms**	Miliseconds
CA	Correspondence Analysis	**OASIS**	Open Affective Standardized Image Set
CATA	Check-All-That-Apply	***p***	*p*-value
CEISH	*Comité de Ética para las Investigaciones relacionadas con Seres Humanos*	**PCA**	Principal Component Analysis
CNS	Central Nervous System	**px**	Pixels
cm	Centimeters	**RATA**	Rate-All-That-Apply
DISFA	Denver Intensity of Spontaneous Facial Action	**s**	Seconds
FACS	Facial Action Coding System	**SCR**	Skin Conductance Response
FC	Food-related context	**VAS**	Visual Analogue Scale
FRIDa	FoodCast research image database	**WC**	Without context
GSR	Galvanic Skin Response	**YRS**	Years old
HD	High-definition		

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1. Introduction

1.1. Children’s food behaviour

Children have become a target for consumer science because they have the ability to influence purchases or even buy food themselves (Laureati et al., 2015). Preference is thought to be an important predictor of food intake (Laureati et al., 2015; Zeinstra et al., 2007) and, in special, children’s food preferences are mainly driven by hedonic factors (Poelman et al., 2017). General patterns of children’s preferences outlined that texture and flavour are the two main attributes that determine food preferences in primary school children for vegetables and fruits (Poelman et al., 2017; Zeinstra et al., 2007).

Children’s food preferences have been traditionally evaluated with hedonic methods based on the measure of liking with scales and preference with ranking tests (Laureati et al., 2015). However, some authors reported that liking is no strong predictor for food choice in real life environments (Dalenberg et al., 2014). Prediction studies conducted with adults (Dalenberg et al., 2014; Juodeikiene et al., 2018) showed that the measurement of the emotions elicited by food products could contribute the understanding of their preferences and food choices. Consequently and taking into account the results obtained with adults, the evaluation of food-evoked emotions in children could provide a deeper understanding of children’s preferences. Additionally, emotions affect eating responses in many ways, such as affective responses to food, amount ingested, and food choices (Spinelli & Monteleone, 2018).

Nevertheless, before conducting a child-centred study is important to bear in mind that the methodology chosen should be adapted to their cognitive, physical, and social stage of development (Guinard, 2001; Laureati et al., 2015), what force researchers to reconsider the existing methodologies to measure food-evoked emotions or to develop new ones if it is necessary.

1.2. Emotion

The debate of what is an emotion has been discussed since Socrates' times (470-399 BC) and it is still far from being ended (Coppin & Sander, 2016). Philosophical, psychological, and affective neuroscience approaches have led to different models that attempt to describe how emotions are elicited and, therefore, determine how emotions can be measured. Among them, there are three major theories of emotion: (i) basic emotion, (ii) dimensional, and (iii) appraisal theories (Coppin & Sander, 2016). Next on this dissertation, the basis of these theories is briefly mentioned, but see Barrett (2006) and Coppin & Sander (2016) for a deeper general description.

The basic emotion theories are based on Darwin's ideas about innate and universal responses transferred by evolution (Darwin, 1872). According to these theories, bio-psychological features such as facial expressions or physiological responses are triggered as a consequence of an stimulus with the aim to help individuals to adapt and to survive (Figure 1; Coppin & Sander, 2016; Ekman, 1994). These theories consider that there is a limited number of emotions, known as "basic" or "discrete" emotions, that meet an evolutionary role. On this regard, different models of emotions have been created, such as Ekman's extensive research (Ekman, 1994, 2003; Ekman & Friesen, 1975; as examples) and the Plutchik's Wheel of Emotions which also considers secondary emotions that are constructed from the primary ones (Plutchik, 1982).

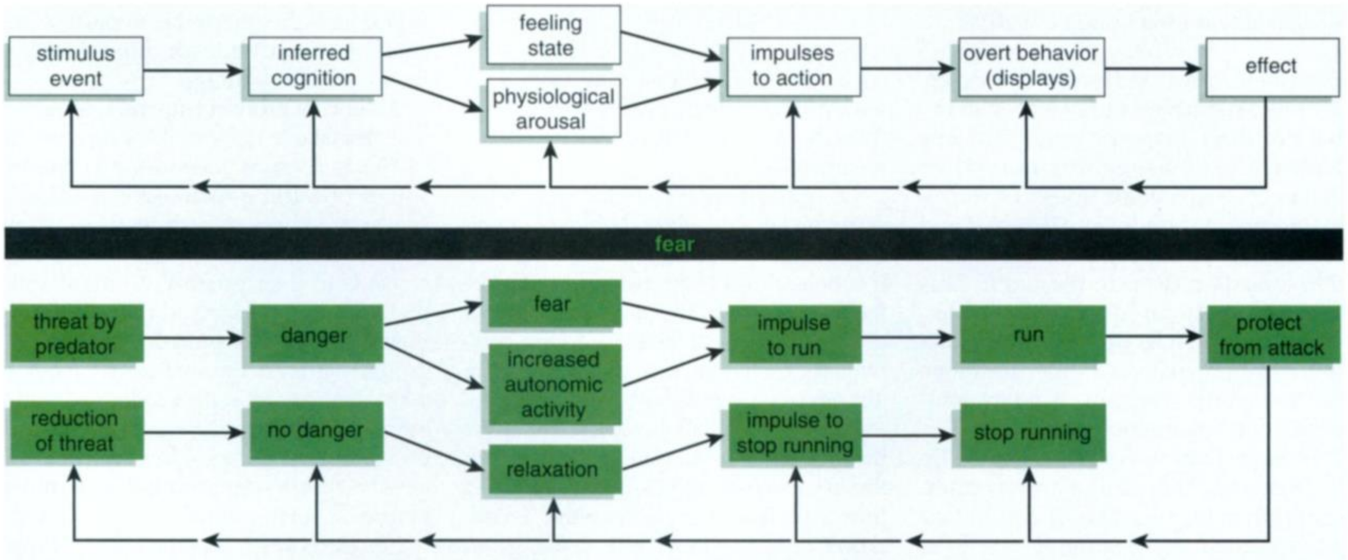

Figure 1. Feedback loop in emotion show how information is evaluated and translated into action that normalises the relationship between the individual and the triggering event according to the basic emotion theory (Plutchik, 2001). An example related to fear is also displayed.

On the contrary, dimensional theories consider emotion as a feeling with different dimensions, such as pleasure/displeasure or excitement/inhibition (Coppin & Sander, 2016). Among the different models of emotion based on these theories, the circumflex model described by Russell (1980) (Figure 2) is the most commonly used for measuring emotional experiences (Coppin & Sander, 2016). This model, also known as core affect, represents emotions as feelings with different degrees of two dimensions: valence (as a continuum of pleasure/displeasure) and arousal (as a continuum of arousal/sleepiness) (Russell, 1980).

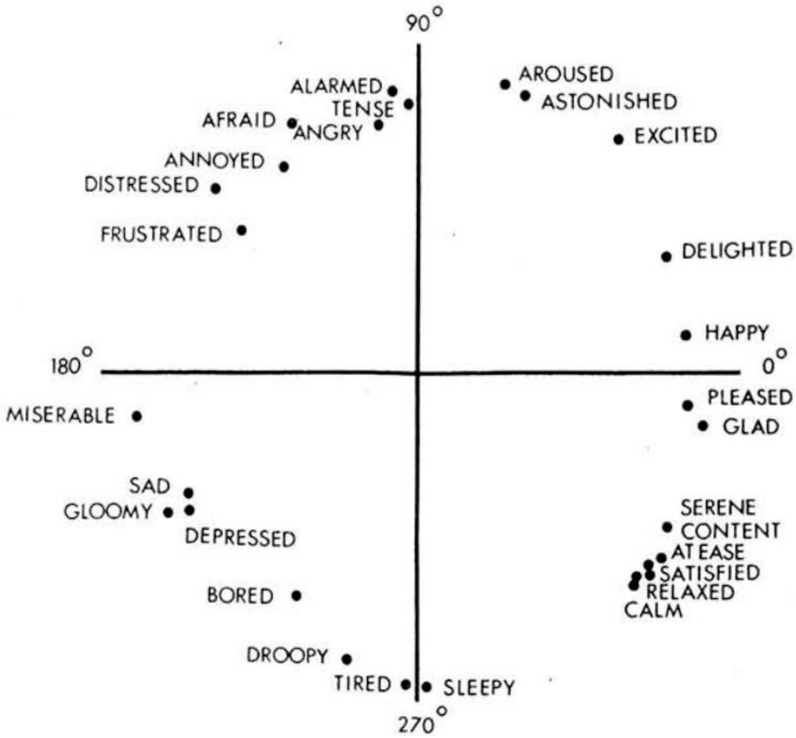

Figure 2. Scaling of 28 emotional terms in the circumplex model of the core affect (Russell, 1980).

Finally, appraisal theories of emotion are based on the belief that individuals explore and experience the environment, cognitively evaluate the stimuli that are available on it and react to the relevant ones by comparing prior experiences that are similar to the present (Barrett, 2006; Hoemann et al., 2019). In this way, a brain is continuously assembling prediction signals that prepare the body for situation-specific action (Hoemann et al., 2019). Contrary to basic emotion theories, appraisal approaches consider that it can be almost limitless number of emotions, but some of them are more frequent or typical than others (Coppin & Sander, 2016).

Overall, these three major theories describe the emotion as a phenomenon with multiple components: (i) an expression which can be facial, vocal, body and posture; (ii) the action tendency related to approach/avoidance behaviours, (iii) bodily and physiological reactions, (iv) feeling or subjective emotional experiences, and (v) appraisal or cognitive processes (Jacob-Dazarola et al., 2016; Sander, 2013). Therefore and according to Coppin & Sander (2016), emotion could be considered as a "brief period of time during which several subsystems of the organism are synchronized to an event considered relevant to an individual's needs, goals, and/or values".

1.2.1. Methods for studying emotions

Considering the theories of the emotion mentioned above, emotions are difficult to measure due to their multidisciplinary character (Jacob-Dazarola et al., 2016). On this regard, the application of methods that aim to evaluate each component of the emotion is necessary to get insights holistically. According to Kaneko et al. (2018), three different approaches can be used for this purpose: (i) cognitive, (ii) behavioural, and (iii) physiological methods.

1.2.1.1. Cognitive methods

Traditionally, emotions have been measured with cognitive methods only reaching information regarding early stages of cognitive processing and consciousness (Kaneko et al., 2018).

Even though a wide variety of methodological variants have been used to evaluate the cognitive component of emotion (i.e. scaling, projecting, Check-All-That-Apply (CATA), among others; Kaneko et al. (2018)) two subgroups of methods can be defined depending on whether they use words or not: i) verbal methods and ii) graphical methods.

1.2.1.1.1. Verbal methods

Word-based questionnaires have been the method more frequently used to evaluate food-evoked emotions due to their ease of application, cost-effectiveness, and discriminative power (Kaneko et al., 2018; Toet et al., 2018). Most verbal questionnaires have been developed to be use with adults (e.g., see generalised questionnaires such as EsSense Profile (King & Meiselman, 2010), EsSense25 (Nestrud et al., 2016), and the Positive Affect Negative Affect Schedule (PANAS; Watson & Clark (1999)) as well as food-specific questionnaires like the ones developed for chocolate and hazelnut spreads (EmoSemio; Spinelli et al. (2014)), beer (Chaya et al., 2015; Mora et al., 2019) and blackcurrant squash (Ng et al., 2013)). Contrary, scarce efforts have been made to design child-friendly verbal lexicon for the study of food-evoked emotions. To the authors knowledge, only two studies aimed to develop an emotional lexicon for flavoured milk (De Pelsmaeker et al., 2013) and sliced sandwich breads (Jervis et al., 2014) for this purpose.

However, word-based questionnaires have several shortcomings: i) emotions are difficult to verbalise, ii) verbal tools demand high cognitive effort, iii) emotional lexicon varies across cultures and languages, and iv) could be inappropriate for groups of population with reduced reading skills (Gutjar, de Graaf, et al., 2015; Köster & Mojet, 2015; Toet et al., 2018).

1.2.1.1.2. Graphical methods

Contrary to verbal methods, graphical tools rely on the human ability to intuitively attribute emotional meaning to graphical elements (Toet et al., 2018). These tools are considered child-friendly since they are intuitive, suitable for groups of population with a reduced capability of reading and demand low cognitive effort (Comesaña et al., 2013; Köster & Mojet, 2015; Toet et al., 2018).

It is thought that graphical tools based on facial expressions are especially intuitive for expressing food-evoked emotions and can be faster processed compared to emotion words (Kaneko et al., 2018; Toet et al., 2018). Among them, three tools are of especial interest: (i) the Self-Assessment Manikin (SAM; Bradley & Lang (1994)), (ii) the Product Emotion Measurement instrument (PrEmo; Desmet (2003)), and (iii) the emoji. Firstly, SAM is a pictorial assessment technique that enables users to rate the dimensional feelings of valence, arousal, and dominance by selecting humanoid figures that best expresses the emotions (Bradley & Lang, 1994). Nevertheless, despite its graphical design, SAM figures related to arousal and dominance are often misinterpreted by both children and adults due to difficulties in their recognition (Hayashi et al., 2016; Toet et al., 2018). Secondly, PrEmo is a non-verbal self-report instrument based on dynamic facial, bodily, and vocal expression that allows users to report and to rate 14 basic emotions (Desmet, 2003). Even though PrEmo has been applied in food studies (Dalenberg et al., 2014; Gutjar, Dalenberg, et al., 2015; He, Boesveldt, et al., 2016; He, de Wijk, et al., 2016), this tool is not context-specific. This lack of specificity could limit PrEmo's relevancy and applicability in the food domain (Gutjar, Dalenberg, et al., 2015; Toet et al., 2018). Additionally, to the authors knowledge, PrEmo has never been used in food studies with schoolchildren.

Lastly, emoji, 'picture word' in Japanese (Ares & Jaeger, 2017), are graphical symbols that represent facial expressions, concepts, ideas, emotions, feelings, objects, animals, plants and activities (Novak et al., 2015). Due to a layout based on facial expressions (Ekman et al., 2002b), facial emoji are considered to be universal, intuitive (Comesaña et al., 2013; Jaeger, Roigard, et al., 2018) and suitable for conducting child-centred research even with young children (Deubler et al., 2019; Fane et al., 2018; Gallo et al., 2017a). Considering that facial emoji were of special interest in this dissertation, a deeper review of the existing knowledge on emoji was included in the following subsections.

1.2.1.1.2.1.Emoji uses in food studies

On the food domain, extensive research has already been carried out on emoji. Until now, emoji-based tools have been developed as unidimensional (Deubler et al., 2019; Swaney-Stueve et al., 2018) and bidimensional scales (Toet et al., 2018), selection (i.e., Check-All-That-Apply (CATA) (Ares & Jaeger, 2017; Gallo et al., 2017b; Schouteten et al., 2018; Sick, Spinelli, et al., 2020) and forced yes/no tools (Ares & Jaeger, 2017)), and rating methods (Ares & Jaeger, 2017; Jaeger, Lee, et al., 2018).

Interestingly, most of this research was done to be applied with adults, whereas scarce studies were focused on pre-adolescents (Sick, Monteleone, et al., 2020; Sick, Spinelli, et al., 2020) and school-aged children (Deubler et al., 2019; Schouteten et al., 2018, 2019; Swaney-Stueve et al., 2018). Additionally, the methodological differences found among studies with children (e.g., the use of different platforms of origin or different question formats) hinders the comparison and general extraction of conclusions.

Until now, emoji were used in studies with schoolchildren to evaluate the emotional response elicited by food names (Deubler et al., 2019), images (Gallo et al., 2017b) and tasting experiences (Schouteten et al., 2018, 2019). Nevertheless, when using emoji in a food study some considerations should be taken into account. The discrimination ability of emoji is thought to depend on the product category of the samples evaluated and on the range of liking. Swaney-Stueve et al. (2018) hypothesised that it is easier to discriminate samples from the same product category than from different categories with the use of emoji. Similarly, emoji are considered to be more discriminative among samples from a broad range of liking than from similar liking ratings (Schouteten et al., 2018). Another methodological feature that should be considered when performing studies with emoji is either to use a specific list of emoji or one of the generalised lists that are already available. Schouteten et al. (2019) concluded that specific lists outperformed the standardise ones in tasting experiences by reducing the inapplicability of the emoji and obtaining higher discrimination among samples.

1.2.1.1.2.2.Limitations of the emoji

Other authors (Kaneko et al., 2018; Sick, Monteleone, et al., 2020; Vidal et al., 2016) reported that facial emoji are not as universal as it was initially thought, identifying differences in their understanding and uses.

The emotions portrayed by the emoji may be misunderstood or differently perceived depending on sociodemographic factors such as age, gender, country and language or the platform of design (Bai et al., 2019). One of the factors that may influence emoji's understanding is context because emoji were designed to have no context specificity (Sick, Spinelli, et al., 2020; Toet et al., 2018).

In this sense, as Jaeger & Ares (2017) highlighted, understanding how consumers perceive the emoji is necessary to conduct emotion studies accurately. Until now, the meaning of emoji has been evaluated through the study of the sentiment and semantic meanings in adults in a free-of-context situation (Jaeger et al., 2019) and in pre-adolescents from 9 to 13 yrs in a food-related context (Sick, Monteleone, et al., 2020). Regarding the sentiment meaning, valence, as a continuum from emotional pleasure to displeasure, and arousal, as a continuum from emotional activation to deactivation, were measured as dimensions of the core affect of emotion (Russell, 1980). Contrary, the semantic meaning (i.e., the definition of the emotion conveyed by the emoji with standardised or self-reported lexicon) provides a discrimination of the emoji based on specific emotion categories rather than on dimensions of the emotion.

1.2.1.2. Behavioural methods

Several components have been related to the behavioural inherent of the emotion such as facial, vocal or verbal expressions (Coppin & Sander, 2016). Facial expressions correspond to changes in the facial configuration due to the movement of facial muscles (Ekman et al., 2002b). Vocal and verbal characteristics include voice tone, volume, fluency of speech, vibration, and the verbal content itself (Jacob-Dazarola et al., 2016). Additionally, body expressions and posture are also considered a behavioural component of the emotion, but their association has been scarcely researched (Jacob-Dazarola et al., 2016). Overall, so far, facial expressions have been the most studied subtype of behavioural expressions (Coppin & Sander, 2016) and were selected as behavioural method for the study of emotions on this dissertation.

1.2.1.2.1. Facial expressions

There are two major ways of understanding facial measurements: direct and indirect methods (Hwang & Matsumoto, 2016). Direct approaches require a direct measurement of the facial muscle movements, whereas indirect approaches rely on observers' judgements.

Among them, the most relevant methodologies used to measure facial expressions are the direct approaches of facial electromyography (EMG) and facial coding. Regarding the former, facial muscles activity is tracked with electrodes attached to the skin surface (Hwang & Matsumoto, 2016). It is a well-established approach to measure facial expressions in adults (Fridlund & Cacioppo, 1986), but it has been scarcely used to study food-evoked emotions with children. Regarding the latter, facial expressions are unravelled through the visual identification of changes in facial configuration (Ekman et al., 2002b). Contrary to EMG, the analysis of facial expressions with facial coding techniques has been extensively used in children from all ages, even in newborns (Ekman & Friesen, 1975; Soussignan & Schaal, 1996; Zeinstra et al., 2009). Due to the special interest of this dissertation on facial coding, this methodology was detailed in depth.

1.2.1.2.1.1.Facial coding

The standard for measuring facial expressions is the Facial Action Coding System (FACS) (Ekman & Friesen, 1976). It is an anatomy-based system that evaluates the movement of facial muscles and turns them into facial expressions. An action unit (AU) is defined as the minimum visible muscular activity that produces momentary changes in facial appearance (Ekman et al., 2002b). Table 1 shows the AUs described by FACS and their muscular basis as well as Figure 3 includes a graphical example.

Interestingly, an AU is not necessarily equivalent to a unique muscle. Sometimes a combination of muscles is required to perform one of the AU (e.g., both *incisivii labii superioris* and *inferioris* are required to perform AU18, lip puckerer (Ekman et al., 2002a)). In the same context, one muscle can perform two different actions (e.g. the *frontalis muscle* produces AU1, inner brow raiser, and AU2, outer brow raiser (Ekman et al., 2002a)).

Table 1. AUs from FACS and their muscle basis (Ekman et al., 2002a).

AU Number	FACS Name	Muscular Basis
1	Inner Brow Raiser	Frontalis, Pars Medialis
2	Outer Brow Raiser	Frontalis, Pars Lateralis
4	Brow Lowerer	Depressor Glabellae; Depressor Supercilli; Corrugator
5	Upper Lid Raiser	Levator Palpebrae Superioris
6	Cheek Raiser	Orbicularis Oculi, Pars Orbitalis
7	Lid Tightener	Orbicularis Oculi, Pars Palebralis
8	Lips Toward Each Other	Orbicularis Oris
9	Nose Wrinkler	Levator Labii Superioris, Alaeque Nasi
10	Upper Lip Raiser	Levator Labii Superioris, Caput Infraorbitalis
11	Nasolabial Furrow Deepener	Zygomatic Minor
12	Lip Corner Puller	Zygomatic Major
13	Cheek Puffer	Caninus
14	Dimpler	Buccinnator
15	Lip Corner Depressor	Triangularis
16	Lower Lip Depressor	Depressor Labii
17	Chin Raiser	Mentalis
18	Lip Puckerer	Incisivii Labii Superioris; Incisivii Labii Inferioris
20	Lip Stretcher	Risorius
22	Lip Funneler	Orbicularis Oris
23	Lip Tightner	Orbicularis Oris
24	Lip Pressor	Orbicularis Oris
25	Lips Part	Depressor Labii, or Relaxation of Mentalis or Orbicularis Oris
26	Jaw Drop	Masetter; Temporal and Internal Pterygoid Relaxed
27	Mouth Stretch	Pterygoids; Digastric
28	Lip Suck	Orbicularis Oris
38	Nostril Dilator	Nasalis, Pars Alaris
39	Nostril Compressor	Nasalis, Pars Transversa and Depressor Septi Nasi
41	Lid Droop	Relaxation of Levator Palpebrae Superioris
42	Slit	Orbicularis Oculi
43	Eyes Closed	Relaxation of Levator Palpebrae Superioris
44	Squint	Orbicularis Oculi, Pars Palpebralis
45	Blink	Relaxation of Levator Palpebrae and Contraction of Orbicularis Oculi, Pars Palpebralis
46	Wink	Orbicularis Oculi

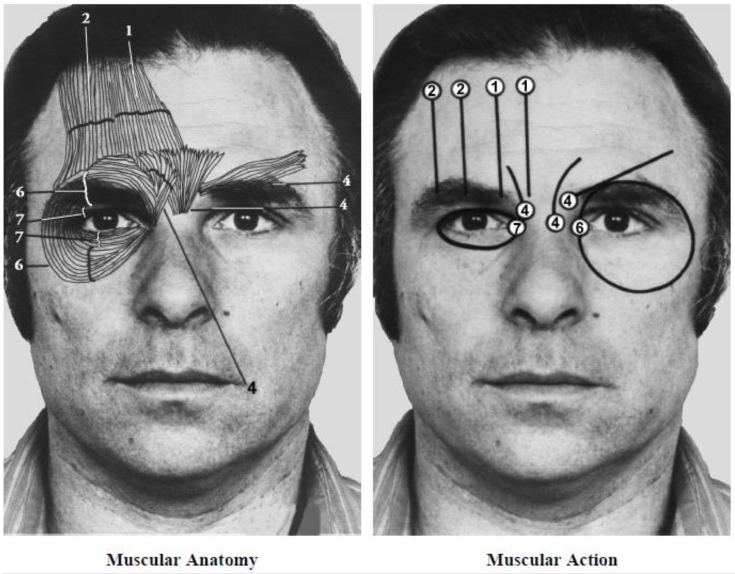

Figure 3. Muscles that underlie the Action Units (AUs) responsible for changing the appearance of the eyebrows, forehead, eye cover fold, and the upper and lower eyelids (Ekman et al., 2002b).

Even though it was not the main objective of Ekman et al.'s research, these authors also identified facial configurations or "blueprints" associated with primary emotions (Ekman et al., 1971; Ekman & Friesen, 1975). In this sense, the activation of different AUs could be considered a behavioural feature for a basic emotion (Figure 4). Nevertheless, the authors also concluded that primary emotions do not have a unique facial configuration, whereas additional facial features may be activated to display a concrete emotion (Ekman & Friesen, 1975).

EMOTION	PROTOTYPES	MAJOR VARIANTS
Surprise	1+2+5B+26 1+2+5B+27	1+2+5B 1+2+26 1+2+27 5B+26 5B+27
Fear	1 +2+4+5*+20*+25, 26, or 27 1+2+4+5*+25, 26, or 27	1+2+4+5*+L or R20*+25, 26, or 27 1+2+4+5* 1+2+5Z, with or without 25, 26, 27 5*+20* with or without 25, 26, 27
Happy	6+12* 12C/D	
Sadness	1+4+11+15B with or without 54+64 1+4+15* with or without 54+64 6+15* with or without 54+64	1+4+11 with or without 54+64 1+4+15B with or without 54+64 1+4+15B+17 with or without 54+64 11+15B with or without 54+64 11+17
	25 or 26 may occur with all prototypes or major variants	
Disgust	9 9+16+15, 26 9+17 10* 10*+16+25, 26 10+17	
Anger	4+5*+7+10*+22+23+25,26 4+5*+7+10*+23+25,26 4+5*+7+23+25, 26 4+5*+7+17+23 4+5*+7+17+24 4+5*+7+23 4+5*+7+24	Any of the prototypes without any one of the following AUs: 4, 5, 7, or 10.

Table note: * means in this combination the AU may be at any level of intensity.

Figure 4. Facial configurations and additional facial features associated with basic emotions according to (Ekman et al., 2002a).

1.2.1.2.1.1.1. Facial coding methods based on FACS

FACS coding requires certified coders who need to demonstrate accuracy and consistency in the identification of facial expressions (Ekman et al., 2002b). The procedure for facial coding generally implies the recording of participants' faces, even though it can be applied to still photographs. Then, at least two coders individually analyse every frame of the recording to evaluate the facial behaviour, referring with this concept to two operations: the description of what happened (which AUs were activated and their intensity) and the location (the precise moment in time when did it happens) (Ekman et al., 2002a). FACS manual (Ekman et al., 2002b) established five levels of intensity scoring based on the movements of the skin and other facial features: A, trace of the action; B, slight evidence; C, marked or pronounced; D, severe or extreme and E, maximum evidence. As (Ekman et al., 2002a) reported, facial coding relies on what is visible to human coders, what might be seen as a limitation of this methodology. In addition, due to its analytical nature, manual facial coding can be tedious and time consuming.

On the other hand, automatic facial coding allows users to analyse the activation of AUs in a faster and less tedious manner. These softwares process the video input frame by frame and measure the activation of the AUs described in FACS. Even though each software has its own engine, a general procedure of automatic facial coding would include the steps shown in Figure 5.

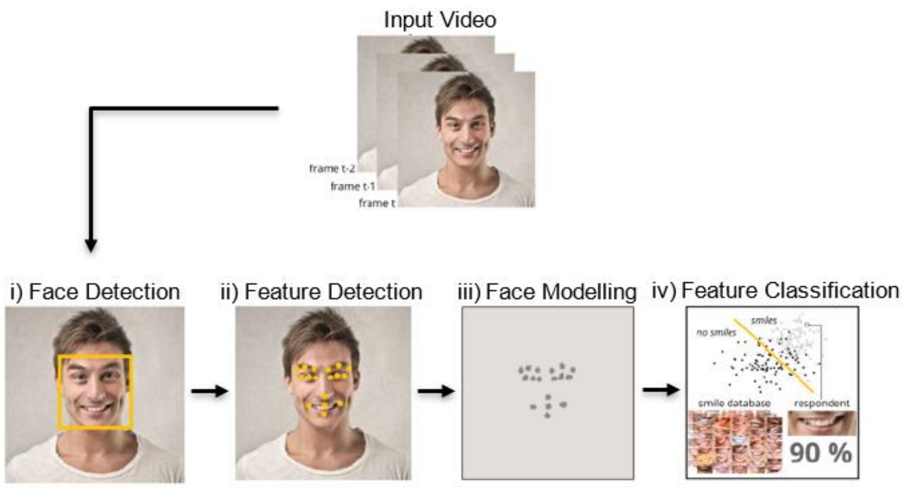

Figure 5. Example of the FACET engine for facial expression and emotion classification based on the procedure exposed in iMotions Biometric Research Simplified (2017): i) Face detection; ii) identification of basic features and landmarks such as the eyes, the nose, and the mouth; iii) development of a model of the face (a simplified version of the respondent's actual face); iv) measurement of landmarks displacements compared to a baseline measure and classification of those displacements in AUs and emotions.

1.2.1.2.1.1.2. Facial coding in food studies

By and large, facial coding has been extensively used to measure food-evoked emotions. Most papers published on this topic were conducted with adult population to evaluate food images (Torrico, Fuentes, et al., 2018), food odours (He et al., 2012, 2014; He, Boesveldt, et al., 2016; He, de Wijk, et al., 2016), and tasting experiences (Bredie et al., 2014; Danner, Haindl, et al., 2014; Danner, Sidorkina, et al., 2014; de Wijk et al., 2014; Dibeklioglu & Gevers, 2020; Fuentes et al., 2018; Horska et al., 2016; Juodeikiene et al., 2018; Kostyra et al., 2016; Leitch et al., 2015; Rocha-Parra et al., 2016; Samant et al., 2017; Torrico, Hutchings, et al., 2018; Walsh et al., 2015, 2017). Unsurprisingly, the number of papers published on the evaluation of the emotions elicited by foods in schoolchildren is scarce and narrows to de Wijk et al. (2012) and Zeinstra et al. (2009).

Even though facial coding provides the possibility to measure both the AUs activation and the display of basic emotion, all the papers mentioned above relied on the codification of basic emotions, except for Dibeklioglu & Gevers (2020) and Zeinstra et al. (2009), who focused their studies on the codification of AUs. This procedure, might be caused by the fact that automatic facial coding softwares showed a more accurate recognition of basic emotions rather than individual AUs in spontaneous facial expressions (Krumhuber et al., 2021; Skiendziel et al., 2019).

1.2.1.2.1.1.3. Limitations of facial coding

Despite its potential in the measure of the behavioural inherent of the emotions, the use of facial coding presents several limitations. The codification of basic emotions relies on the belief that prototypical facial expressions coded emotional responses (Ekman et al., 2002a; Ekman & Friesen, 1975). Nevertheless, this theory is still under debate for many reasons. On the one hand, it is though that the spontaneous expressions that are common in everyday life are far from being prototypical, but also emotionally ambiguous, relatively subtle and more difficult to recognised compared to prototypical or posed expressions (Krumhuber et al., 2017, 2021).

On the other hand, the emotional meaning of facial expressions depends on the level of consciousness involved. The display of unconscious facial expressions may rely on survival reasons, with the objective to provide important information to prevent potential risks, such as the ingestion of poisoning substances (de Wijk et al., 2012; Zeinstra et al., 2009). On the contrary, it is though that the facial expressions displayed in consciousness can be voluntarily controlled with the ultimate purpose to support communication in social settings (Cernea & Kerren, 2015; Song et al., 2016). On this regard, children as young as five yrs have proved to modulate their facial expressions in social environments (Soussignan & Schaal, 1996).

Another limitation frequently related to facial coding is the lack of context during the codification process. This methodology does not consider the environment in which a facial expression is displayed hindering the identification of the underlying reasons that trigger the behaviour (Prescott, 2017; Spinelli & Monteleone, 2018).

Additionally, one last limitation that is especially relevant in the food domain relies on the alteration of the facial configuration that is caused during in-mouth manipulation of food products, what could lead to misclassification

(Lagast et al., 2017; Samant et al., 2017; Spinelli & Monteleone, 2018; Zeinstra et al., 2009).

1.2.1.3. Physiological methods

Physiological measures focus on the subconscious responses of the human body that are raised in the central nervous system (CNS) and the autonomic nervous system (ANS) (Cernea & Kerren, 2015). While the CNS controls the activity of the brain, the ANS is responsible for modulating peripherical functions (Spinelli & Monteleone, 2018). ANS physiological responses are thought to be a manifestation of emotional experiences (Kreibig, 2010), as well as other body functions such as digestion and homeostasis (Spinelli & Monteleone, 2018). On this regard, ANS measures can be classified on the responses that are controlled by the sympathetic system which is associated with emotion (i.e., electrodermal activity (EDA), the heart rate, the skin temperature, respiratory rates, and pupillometry, among others (Kreibig, 2010)) and on the responses controlled by the parasympathetic system which is related to emotion (Stasi et al., 2018) as well as other body functions such as digestion (iMotions Biometric Research Simplified, 2015).

According to Spinelli & Monteleone (2018), the measure of the brain activity (CNS responses) in the context of food studies is still limited. On the contrary, the measure of ANS responses has been extensively used to measure food-evoked emotions in the last decade (de Wijk et al., 2014; He et al., 2014; He, de Wijk, et al., 2016; as examples), specially the electrodermal activity (Braithwaite et al., 2015).

1.2.1.3.1. Electrodermal Activity (EDA)

EDA, also known as Galvanic Skin Response (GSR), is the term used for defining autonomic changes in the electrical properties of the skin. The EDA complex includes two components (Figure 6): (i) a background tonic phase (also named as Skin Conductance Level, SCL) and (ii) a rapid phasic phase (also named as Skin Conductance Responses, SCR) (Braithwaite et al., 2015). Even though both phases on the conductance signal are nowadays thought to reflect an emotional response (Braithwaite et al., 2015), only changes in SCR were traditionally considered as event-related (iMotions Biometric Research Simplified, 2015).

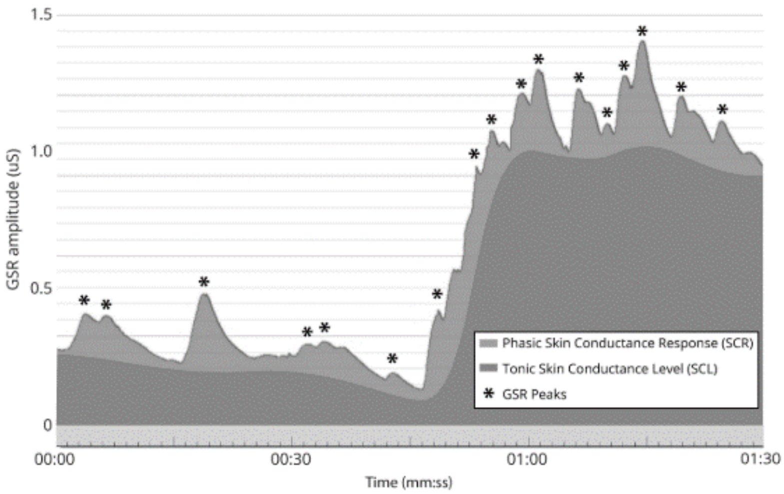

Figure 6. Common curve of the electrodermal activity (EDA), in which two phases are differentiated: tonic phase (SCL) and phasic phase (SCR) (iMotions Biometric Research Simplified, 2015). GSR peaks correspond with raises in SCR over a specific threshold.

The EDA is measured by passing a small current through two electrodes placed on the surface of the skin. The electrodes monitor the evolution of the electrical properties of the skin caused by changes in the activity of the sweating glands (Dawson et al., 2000; Stasi et al., 2018). One characteristic of

EDA responses that should be considered when monitoring this type of physiological measure is that changes in SCR have a latency period between the initial raise of the signal (i.e., the onset) and the first significant deviation in the signal (i.e., the peak) of 1-3 seconds (Braithwaite et al., 2015).

1.2.1.3.1.1.EDA in food studies

Until now, the emotional connotation of EDA responses and the effect of pleasant and unpleasant stimuli on the skin conductance response has been largely debated reaching inconclusive results independently of the group of population evaluated (i.e., children or adults) (de Wijk et al., 2012; He et al., 2012; Samant et al., 2017). One theory established that increases in SCR could be associated with negative emotions like anger, anxiety or disgust, but also with positive emotions such as amusement, joy, and anticipatory pleasure (Kreibig, 2010).

1.2.1.3.1.2.Limitations of EDA measures

The fact that changes in EDA could be triggered by an emotional event or by other body functions characterises EDA as an unspecific measure (Dawson et al., 2000). Consequently, this lack of specificity hinders the identification of patterns for emotional responses (i.e., no clear associations have been established until now between increases (or decreases) in EDA responses an specific emotional responses; Kreibig (2010)). Traditionally, ANS measures have been considered to be related to specific emotions (Alaoui-Ismaïli et al., 1997). Nevertheless, studies conducted in the last decades suggested that ANS responses are related to dimensional responses such as arousal or valence rather than discrete emotions (de Wijk et al., 2012; Kreibig, 2010; Spinelli & Monteleone, 2018). For an extensive and detailed review about the up-to-date studies conducted on the associations established between ANS responses and discrete emotions, see Kreibig (2010).

Another important limitation of EDA measures relies on their physiological character. EDA responses are dependent of individual differences, being influenced by psychopathological states or individual responsiveness, among others (Dawson et al., 2000).

2. Hypothesis & Objectives

Most theories of emotion agree to belief that emotions have a multicomponent character. On this regard, different levels of emotional processing should be considered to reach an holistic perspective of food-evoked emotions. Cognitive methods rely on self-reported responses and frequently include the use of questionnaires to deepen into the feeling inherent of emotion. Physiological responses manifest bodily reactions that are involuntary controlled. Additionally, behavioural methods analyse the expression of the emotion into facial, body, or vocal changes among other.

When conducting a study with children it is necessary to bear in mind that methodologies designed for adult should be adapted to children's cognitive, physical and social stage of development (Guinard, 2001; Laureati et al., 2015). This dissertation emerged to develop child-friendly methodologies capable of measuring cognitive, physiological, and behavioural responses elicited by food products.

In this sense, the aim of this doctoral thesis was to develop a novel approach consisting of combining a cognitive, physiological, and behavioural responses to elucidate an holistic perspective of the emotional response elicited by food products in schoolchildren. To achieve this general aim different partial objectives were established:

- To understand how schoolchildren perceive facial emoji dimensionally and semantically, and to evaluate the influence of social and demographic factors on this perception (Study 1).
- To identify a group of food-specific emoji to shape a child-friendly emoji-based tool (Study 2).

- To evaluate the applicability of the emoji-based tool in studies with evoked food names and images (Study 2) as well as with real food samples (Study 3).
- To validate the applicability of automatic facial coding for the recognition of spontaneous facial expressions displayed in the food domain (Study 4).
- To design a combined methodology that ensure a correct applicability of automatic facial coding and the measure of the skin conductance response in a varied range of sensory tasks, including the consumption of food products, and providing information about the context in which the testing experience takes place (Study 5 and Study 6).

Additionally, while the main aims of this dissertation were assessed, we evaluated other secondary objectives also focused on the emotional response induced by food products in schoolchildren:

- To determine how different types of food stimuli influence food-evoked emotions in schoolchildren (Study 2 and Study 3).
- To elucidate how food textures modulate food-evoked emotions in schoolchildren (Study 3, Study 5, and Study 6).

3. Materials & Methods

3.1. Development of the emoji-based tool

3.1.1. Initial selection of emoji and emotion lexicon development

3.1.1.1. Emoji

The preselection of the emoji to be used in this dissertation was based on two papers published on this topic. The 33 facial emoji described by Jaeger, Vidal, et al. (2017) and the 50 emoji evaluated by Gallo et al. (2017) were selected. Duplicate emoji between both studies were only considered once. As a result, Table 2 shows the list of 41 emoji selected from both papers, their description and their Unicode number extracted from the Emojipedia (Emojipedia, 2020). However, contrary to these authors who used the Apple version, the open-source version 4.5 (Joy Pixels, Inc., Henderson, NV) of these emoji was examined in this dissertation.

Table 2. List of the emoji used in the pre-test. Codes correspond with each emoji standardised number in Unicode. Descriptions correspond with the emoji's Unicode name as found in Emojipedia.

Code	Emoji	Description	Code	Emoji	Description
U+1F620	😠	Angry face	U+1F62C	😬	Grimacing face
U+1F616	😖	Confounded face	U+1F600	😀	Grinning face
U+1F615	😕	Confused face	U+1F601	😁	Grinning face with smiling eyes
U+1F622	😢	Crying face	U+1F62D	😭	Loudly crying face
U+1F625	😥	Disappointed but relieved face	U+1F610	😐	Neutral face
U+1f61E	😞	Disappointed face	U+1F623	😣	Persevering face
U+1F62B	😫	Distraught face	U+1F621	😡	Pouting face
U+1F611	😑	Expressionless face	U+1F60C	😌	Relieved face
U+1F60B	😋	Face savouring delicious food	U+1F614	😔	Sad pensive face
U+1F631	😱	Face screaming in fear	U+1F634	😴	Sleeping face
U+1F618	😘	Face throwing kiss	U+263A	☺️	Smiling face

U+1F613	😓	Face with cold sweat	U+1F60D	😍	Smiling face with heart-shaped eyes
U+1F630	😰	Face with open mouth and cold sweat	U+1F604	😄	Smiling face with open mouth and smiling eyes
U+1F61B	😛	Face with stuck-out tongue	U+1F60A	😊	Smiling face with smiling eyes
U+1F61D	😝	Face with stuck-out tongue and tightly closed eyes	U+1F60E	😎	Smiling face with sunglasses
U+1F61C	😜	Face with stuck-out tongue and winking eye	U+1F60F	😏	Smirking face
U+1F602	😂	Face with tears of joy	U+1F612	😒	Unamused face
U+1F633	😳	Face with wide open eyes	U+1F629	😩	Weary face
U+1F636	😶	Face without mouth	U+1F609	😉	Winking face
U+1F628	😨	Fearful face	U+1F61F	😟	Worried face
U+1F626	😦	Frowning face with open mouth			

3.1.1.2. Participants

Three focus group were performed with a total of 20 children from 6 to 12 yrs (35% girls, 65% boys) after school at AZTI's facilities in two consecutive days. This broad range of age includes two stages of cognitive development: the pre-operational stage (beginning readers) and the concrete operational stage (pre-teen) (ASTM E2299 - 13. Standard Guide for Sensory Evaluation of Products by Children and Minors, 2013; Brouse & Chow, 2009). However, to have a manageable number of participants in each session (6-7 children per focus group), scholars were divided in three age-groups. For this task, seven children from 1st and 2nd year of elementary school (4 boys, 3 girls), seven children from 3rd and 4th year (4 boys, 3 girls), and six children from 5th and 6th year (5 boys, 1 girl) were recruited. Parents of the participants received and signed an informed consent before children initiated the study. The participants aged below 12 yrs gave oral consent to participate in the study, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki.

3.1.1.3. Experimental procedure

Three focus groups were conducted to visualised how children interpreted the initial set of facial emoji. Each session was audio recorded and recordings were afterwards reviewed to extract results. Each focus group session took about 90-minute to complete.

3.1.1.3.1.Preselection of emoji

The emoji were shown in a randomised order and children were individually asked to classify the emoji into valence categories (i.e., "positive", "negative", "neutral" or "I don't know") with the question *"how positive or negative do you think is the emotion that the emoji conveys?".* Afterwards, a group discussion was carried out to reach a consensus among participants. Emoji classified without a consensus among the three groups or as “I don’t know" were discarded due to ambiguity.

3.1.1.3.2.Development of an emotion word list

The emotional meaning associated with the emoji chosen in the preselection task was identified by recording the children’s spontaneous words given to the question “*which emotion or feeling do you think that the emoji tries to convey?*”. After each focus group took place, a researcher reviewed the recordings and extracted the terms and expressions provided to describe each emoji. Similar words (i.e., happy and very happy) were not grouped to ensure that the lexicon was available like the children provided it. At this point, only words with an emotional meaning were considered, and physical descriptions were discarded. Consequently, emoji for which no emotion words were provided were also discarded and not considered in further studies. The relevancy of the words given by the children was measured by differing between (i) terms that emerged in the three focus groups and (ii) terms provided only in one or two groups of children.

3.1.2. Evaluation of the emoji’s meaning

3.1.2.1. Emoji

The facial emoji that had an emotional meaning during the initial selection (section 3.1.1.) were further studied. However, these emoji lacked some emotions that could be potentially relevant to describe foods in children. Sick, Spinelli, et al. (2020) associated emoji that conveyed disgust with dislike, and they also reported that emoji which portrayed emotions such as surprise or indifference could be relevant for pre-adolescents. Consequently, at this point we decided to include 6 additional emoji that mainly conveyed surprise (i.e., *anguished face* (😧), *astonished face* (😲)and *surprised face* (😯)), disgust (i.e., *face with open mouth vomiting* (🤮) and *nauseated face* (🤢)), and contempt (i.e., *face with rolling eyes* (🙄)) (Emojipedia, 2020).

3.1.2.2. Emotion lexicon

To obtain a short list of emotion terms with no more than 20-25 items, as suggested by Schouteten et al. (2019), only the emotion words that were repeated along the three focus groups initially conducted (section 3.1.1.) were used. Additionally, the emotion words that defined the emotion portrayed by the six additional emoji were exclusively extracted from Emojipedia[1] (Emojipedia, 2020).

3.1.2.3. Participants

A total of 312 children from 6 to 12 yrs (49% girls, 51% boys) with a mean age of 9.2 ± 2.0 yrs were recruited via primary schools in Bizkaia (Spain). This study was conducted during the lockdown, so each participant answered the online survey at home by tablet or computer, while smartphones were discouraged due to the survey layout. Signed parental informed consent was required to be eligible to participate in the study. The participants aged below 12 yrs gave oral consent to participate, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki and the study protocol was approved by CEISH, the Basque Country University's Ethical Committee.

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[1] Emotional definitions extracted from Emojipedia (Emojipedia, 2020): (i) *anguished face*: surprised, sad; (ii) *astonished face*: surprised; (iii) *surprised face*: surprised; (iv) *face with open mouth vomiting*: disgust; (v) *nauseated face*: disgust; and (vi) *face with rolling eyes*: bored.

3.1.2.4. Experimental procedure

The study was designed as two surveys. Both questionnaires shared a basic structure; however, one of them evaluated the perception of the emoji in a free-of-context situation and the other included an evoked food-related context. In the latter, the following wording was placed before each emoji: "*Imagine that it is weekend, and you are having lunch with your family. You start to share your meal with them and when you bite and taste your food, you act like the following emoji. Please, answer the questions considering this situation*". An incomplete experimental design was followed in which each child evaluated 15 out of the 30 emoji presented in a monadically and randomised order (over 70 complete answers per survey versions).

After explaining the concepts involved in the test (i.e., valence and arousal), a training trial was conducted to get the children used to the questions that appeared in the questionnaire. Children were asked to not go any further if they do not understand the training questions and parents were asked to call or email the researchers if they had any question about the survey. After this training, the semantic meaning of the emoji was evaluated with the question "*which emotion or feeling do you think that the emoji tries to convey?*" in CATA format. The emotion lexicon developed in section 3.1.1. was randomly placed in columns for each participant. The option "none of them" was included. Then, valence and arousal dimensions were assessed using a 100-units Visual Analogue Scale (VAS). Based on the suggestion of Toet et al. (2018), the arousal concept was replaced with the intensity of the emotion in order to simplify its understanding. In addition, questions about demographics (age and gender) and the frequency of use of smartphones and tablets (3-pt scale labelled as "frequently", "sometimes", and "never") were also included at the end of the survey. The distribution of both questionnaires was balanced and randomised among the participants. The survey took up to 15 minutes to complete.

3.1.2.5. Statistical analysis

Fisher's exact test was performed on sociodemographic and use of smartphones/emoji frequency data to verify the absence of significant differences among the two populations that participated in the study. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.1.2.5.1. Dimensional meaning

Based on the representation of results from Jaeger et al. (2019), valence and arousal categorisation of each emoji was performed according to the average scores. Regarding valence, the following classification was performed: i) "negative": for the emoji that obtained a mean valence score from 0 to 33; ii) "neutral": for the emoji with a mean valence score from 34 to 66 and iii) "positive": for the emoji that scored a mean valence rating from 67 to 100. Similarly, the following classification was performed regarding arousal: i) "relaxed": for the emoji that obtained a mean arousal score from 0 to 33; ii) "neutral": for the emoji with a mean arousal score from 34 to 66 and iii) "active": for the emoji that scored a mean arousal rating from 67 to 100.

ANOVA and Tukey's post hoc test was performed on raw data to identify significant differences on valence and arousal ratings considering the emoji, age, gender, and the context as fixed factors as well as their interactions. Additionally, individual comparisons of valence and arousal ratings in the free-of-context and the food-related context situations were carried out with

Student's t test. Two age groups, 6-8 yrs and 9-12 yrs, were established to identify the effect of age.

3.1.2.5.2.Semantic meaning

To evaluate the semantic meaning of the emoji, the child-friendly emotion lexicon used in the study was clustered into emotion word categories because of the presence of similar terms. This classification was done considering that the words or short phrases provided by the children included the own category or synonyms. This procedure was done after the survey took place to ensure that the lexicon was available in the same manner that it was developed. The clusterisation procedure was as follows: i) "happy", "very happy" and "extremely happy" were clustered in the "happy" category; ii) "sad", "extremely sad" and "a bit sad" were included in "sad" category; iii) "very angry" and "extremely angry" were clustered as "angry"; and iv) "affectionate" and "loving" were included in "love" category. On the contrary, the other emotion terms used in the study built emotion word categories on their own because of the absence of synonyms ("bored", "disgust", "serious", "scared", "ashamed", "content", "surprised", "joking" and "no comments").

Frequency of use of the lexicon was calculated by counting the number of participants that selected each category for the emoji. Fisher's exact test was performed on frequency data to evaluate the effect of age, gender, and context on the semantic meaning of the emoji. Two age groups were considered, 6-8 and 9-12 yrs. Correspondence Analysis (CA) was applied to graphically represent the associations between the emoji and the emotion word categories.

3.1.3. Identification of food-specific emoji

3.1.3.1. Emoji

In this study the 30 facial emoji whose dimensional and semantic meaning was examined in section 3.1.2. were used.

3.1.3.2. Participants

A group of 154 children from 6 to 12 yrs (48% girls, 52% boys) with a mean age of 9.3±2.0 yrs were recruited via primary schools in Bizkaia (Spain). The questionnaire was completed at home by tablet or computer, while smartphones were discouraged due to the survey layout. A signed parental informed consent was required to be eligible to participate. The participants aged below 12 yrs gave oral consent to participate in the study, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki and the study protocol was approved by CEISH, the Basque Country University's Ethical Committee.

3.1.3.3. Survey design

An online survey was developed to identify food-specific emoji from the 30 emoji initially considered. For this purpose, children were asked to choose which emoji conveyed the emotions elicited by seven food-related situations evoked as written stimuli. The contexts chosen were: i) a general food-related situation (i.e., emoji that could be applicable to describe the emotions elicited by food), imagining eating food products that represented a product that you ii) like very much, iii) like, iv) neither like nor dislike, v) dislike, vi) dislike very much, and vii) a situation in which the food product is refused, and you denied eating. The emoji were displayed in columns and in randomised order in a CATA question. The option "none of the emoji" was also available.

3.1.3.4. Statistical analysis

Frequency of use of the emoji was calculated by counting the number of participants that selected each icon for the different situations evoked. Significant differences among contexts were evaluated using Cochran's Q test and Sheskin test. Only emoji with frequencies of use equal or over 20% of the participants for at least one context were considered as food specific. Among them, strong associations were established for frequencies equal or over 50% of the participants. Hierarchical cluster analysis on centred frequencies of use was performed to explore redundancies among facial emoji. Euclidean distances and Ward agglomeration criterion were considered. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.2. Applicability of the emoji-based tool in the study of the emotions elicited by food

3.2.1. Evoked food names and images as stimuli

3.2.1.1. Emoji

The applicability of the non-redundant food-specific emoji identified in the section 3.1.3 of this dissertation was evaluated.

3.2.1.2. Participants

A total of 95 children from 6 to 12 yrs (46% girls, 54% boys) with a mean age of 9.0±1.7 yrs were recruited via primary schools in Bizkaia (Spain). The questionnaire was completed at home by tablet or computer, while smartphones were discouraged due to the survey layout. A signed parental informed consent was required to be eligible to participate in the study. The participants aged below 12 yrs gave oral consent to participate, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki and the study protocol was approved by CEISH, the Basque Country University's Ethical Committee.

3.2.1.3. Samples

To study the food-specific emoji's applicability, a selection of food products frequently eaten at breakfast or snack were evoked. The specific samples were three types of biscuits (Marie style biscuit, a sample with chocolate chips, and a biscuit with dehydrated fruit), a cupcake, cornflakes, and an apple. The considerations taken when selecting the food stimuli were to include: (i) samples from the same product category (biscuits); (ii) samples from different product categories (other bakery goods and fruit), and (iii) samples that covered a broad range of the hedonic continuum. On this regard, we hypothesised that all samples would be expected to be slightly or very liked (Pérez-Rodrigo et al., 2003), except the biscuit with dehydrated fruit which would be expected to dislike based on prior research (da Quinta et al., 2021; Sandvik et al., 2021).

3.2.1.4. Experimental procedure

An online survey was carried out to evaluate the applicability of the emoji-based tool on terms of sample discrimination. All food products were firstly evoked as food names and secondly as food images. Samples were presented in a randomised order and participants were asked to complete two questions for each stimulus: i) "*how much would you like eating <food name/image>?*" with a 7-point hedonic scale anchored at 1 = "extremely disliked" and 7 = "extremely liked"; and ii) "*how would you feel eating <food name/image>?*" with the food-specific emoji randomly displayed in a CATA question. The option "none of the emoji" was available.

3.2.1.5. Statistical analysis

ANOVA and Tukey's test were performed on raw data to examined differences in the expected liking of the samples. Products and consumers were considered as fixed factors. Frequency of use of emoji was calculated by counting the number of participants that selected each icon for the stimuli. Significant differences among samples were evaluated using Cochran's Q test and Sheskin post-hoc test. CA was carried out on frequency data to graphically visualise the discrimination ability of the emoji among samples. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.2.2. Real food samples as stimuli

3.2.2.1. Emoji

The applicability of the non-redundant food-specific emoji identified in section 3.1.3. of this dissertation was evaluated.

3.2.2.2. Participants

A total of 50 children from 5 to 12 yrs (54% boys, 46% girls) with a mean age of 8.0+2.0 yrs were recruited from AZTI's database. To be eligible to participate in the study, parents signed an informed consent before the experimental session began. The participants aged below 12 yrs gave oral consent to participate in the study, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki and the CEISH, the Basque Country University's Ethical Committee, approved the study protocol.

3.2.2.3. Samples

Six texture-modified food products that ranged from slightly thick liquid to regular solid food (Figure 7) were designed and developed from apple juice, according to the IDDSI framework of the *International Dysphagia Diet Standardisation Initiative* (IDDSI, 2019). No more than six products were considered to prevent fatigue and boredom. Table 3 showed the description of each food product and the ingredients used for their design.

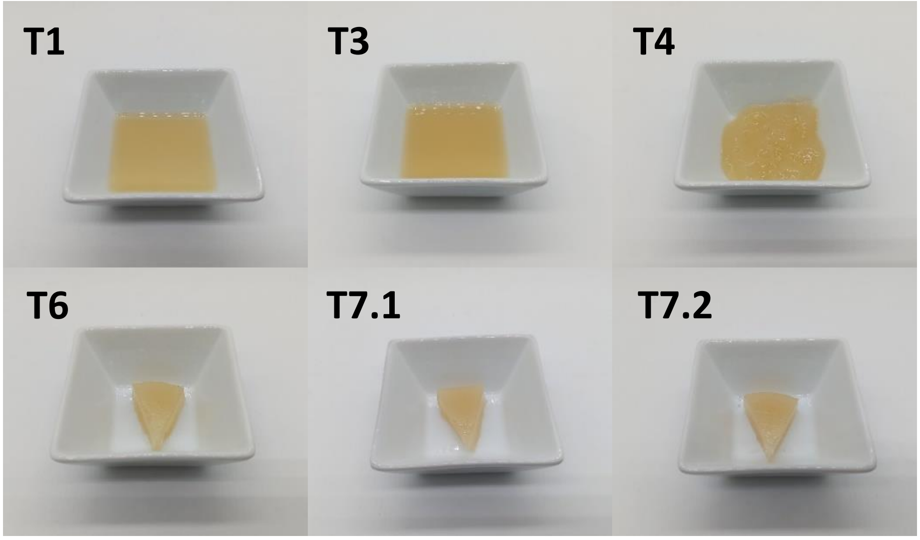


Figure 7. Texture-modified food samples designed according to the International Dysphagia Diet Standardisation Initiative (IDDSI, 2019) levels: 1, 3, 4, 6, 7-easy to chew (as 7.1) and 7-regular (as 7.2).

Table 3. Description of the six texture-modified samples design according to the International Dysphagia Diet Standardisation Initiative (IDDSI, 2019). Code column shows the label used to describe each sample throughout this work, which was designed to match the texture levels of IDDSI.

IDDSI level	Code	Texture	Ingredients
1 - Slightly thick	T1	Liquid	Apple juice, xanthan gum, and guar gum
3 - Moderately thick	T3	Liquid	Apple juice, starch, xanthan gum, and guar gum
4 - Extremely thick	T4	Liquid	Apple juice, starch, xanthan gum, and guar gum
6 - Soft & Bite-sized	T6	Solid	Apple juice, starch, carrageenan, xanthan gum, guar gum, and natural apple flavour
7 - Easy to chew	T7.1	Solid	Apple juice, sugar, garrofin gum, carrageenan, citric acid, and natural apple flavour
7 - Regular	T7.2	Solid	Apple juice, sugar, garrofin gum, carrageenan, citric acid, and natural apple flavour

Similar to Laureati et al. (2017), apple flavour was selected in this study to avoid an extreme rejection behaviour. To match the flavour and the sweet-sour tastes over all the samples, it was necessary to add natural apple flavour to the solid prototypes as well as citric acid and sugar in two of them. The portion of each product evaluated in the study was 16 g per sample.

3.2.2.4. Experimental procedure

Each participant evaluated all samples in one session individually. After explaining the experimental procedure to the child, a training task was performed to get each subject used to answer the hedonic and emotional questions involved in the study. After a positive training, a researcher placed one of the food samples on the table in front of the participant and the subject was asked to perform the following actions in order and with no time restrictions: i) to observe, ii) to smell, iii) to manipulate the sample with a spoon (for liquid samples and T6) or with the fingers (for T7.1 and T7.2), and iv) to consume the sample with a spoon (for liquid samples and T6) or with the fingers (for T7.1 and T7.2). Afterwards, children were asked to rate how much they liked the sample tasted with a 7-point hedonic scale anchored at 1=”extremely disliked” and 7=”extremely liked” and to report the emotion elicited by the product with the list of food-specific emoji displayed in a Rate-All-That-Apply (RATA) layout with a 3-point scale anchored at “low”, “medium” and “high”.

The procedure was then repeated with all the samples. Still water was served for cleansing the palate between products. All participants evaluated the samples in a fixed order from starting with T1 and ending with T7.2 to minimise fatigue and to facilitate the identification of texture differences among samples.

3.2.2.5. Data analysis

Due to the different composition and evaluation procedure followed during the manipulation and the consumption tasks for liquid and solid samples, the results obtained for liquid and solid prototypes were analysed separately. ANOVA and Tukey’s post hoc test were performed on raw liking data to identify significant differences among liquid and solid samples. Products and consumers were considered as fixed factors. According to Meyners et al. (2016) suggestions, RATA data was analysed by means of the intensity of the emotion reported by the children considering 0 = "emoji not selected", 1 = "low", 2 = "medium", and 3 = "high" (henceforth mean RATA). Additionally, RATA data was analysed as a CATA layout, for which only the frequency of choice of the emoji for each sample was considered, and not the intensity of the emotion (henceforth RATA-as-CATA). This procedure was discouraged by Meyners et al. (2016) in studies with adults for decreasing the sample discrimination, but it has never been evaluated with children. Multivariate analysis was performed to examine each sample configuration and the sample discrimination reached with the emoji-based tool. On this regard, CA was carried out on RATA-as-CATA data, while PCA was performed on mean RATA data. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.3. Validity of automatic facial coding for the recognition of spontaneous expressions in food studies

3.3.1. Recognition of Action Units (AUs)

3.3.1.1. Database

No standard database with AUs information was found associated with the food context. Consequently, the Denver Intensity of Spontaneous Facial Action (DISFA) database, which includes recordings from the spontaneous faces of 27 subjects recorded while watching a 4-minutes selection of scenes, was considered for the validation study. The database included recording from a left and right front camera, but for this work only right videos were considered. In the validation study (Mavadati et al., 2013), each frame of the recordings (4845 frames per video, 130815 frames in total) were manually coded by a FACS coder (Ekman et al., 2002) with the following AUs: AU01, AU02, AU04, AU05; AU06, AU09, AU12, AU15, AU17, AU20, AU25, and AU26. Even though the database provided the intensity of the activation of each AU, only the presence or absence of an AU was considered as described in the FACS manual (Ekman et al., 2002a).

3.3.1.2. Automated facial expression software

The FaceReader software (version 8.0, Noldus Information Technology, Wageningen, The Netherlands) was used to code 20 AUs in each frame of the DISFA recordings. FaceReader provided probability-like values (henceforth intensity) for 20 AUs in a 0 to 1 scale, in which 0 is the absence of the AU activation and 1 the highest probability to match with a FACS coder.

3.3.1.3. Experimental procedure

Each frame of the DISFA recordings was processed with FaceReader without calibration due to the lack of a baseline or neutral stimuli.

3.3.1.4. Data analysis

As suggested by Lewinski et al. (2014), the recognition ability of the software for the AUs was measured as precision, recall, F1 and accuracy metrics. *Present* refers to the number of frames for which an AU was coded as activated in the database. *Precision* is a ratio that consider the frames correctly classified by the software from all the frames in which an AU was originally coded in the database (i.e., hits + false negative errors). *Recall* is a ratio that consider the frames correctly classified by the software from all the frames for which the software coded an AU as activated (i.e., hits + false positive errors). The *F1* measure is a trade-off between precision and recall computed by the formula: $2 * [(\text{Precision} * \text{Recall})/(\text{Precision} + \text{Recall})]$. *Accuracy* represents the percentage of correct classifications performed by the software when an AU was correctly classified as present and absent.

3.3.2. Recognition of the emotional response elicited by evocative images

3.3.2.1. Participants

A total of 40 children from 6 to 13 yrs (62% boys and 38% girls) with a mean age of 8.5+2.0 yrs were recruited from AZTI´s database. To be eligible to participate in the study, parents signed an informed consent before the experimental session began. The participants aged below 12 yrs gave oral consent to participate in the study, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki. The results of four children were finally discarded due to a low quality.

3.3.2.2. Databases

The databases included in this study were designed to elicit an emotional response in the subjects that look at them. Images from two standardised databases were included for different purposes.

3.3.2.2.1. Open Affective Standardized Image Set (OASIS)

This set includes images from a broad range of topics. It was considered for the validation study because their images can elicit an emotional response that covers a broad range of the valence and the arousal dimensions (Kurdi et al., 2017). A first selection of pictures was developed by two researchers to remove sensitive images not appropriated for the children (e.g., images of sexual content). Afterwards, a second selection of images was performed by the same researchers to reduce the number of pictures to be used in the study. Consequently, a total of 48 images were chosen to cover all span of valence and arousal. The codes of the images selected for the study and their distribution in the valence and arousal plot are shown in Appendix 1.

3.3.2.2.2.The FoodCast research image database (FRIDa)

FRIDa database was selected to evaluate the emotional response specifically elicited by food images. Similarly to the OASIS database, an initial selection of images was carried out to remove non-food images. A second selection was done by two researchers to reduce the number of images to be included in the study. Finally, a group of 18 food images that covered a broad range of the valence and arousal dimensions were identified. The codes of the images selected for the study and their distribution in the valence and arousal dimension plot are shown in Appendix 2.

3.3.2.3. Automated facial expression software

FaceReader 8.0 was used to analyse the facial expressions of each participant during the observation of the standardised images. Data was collected at a sampling rate of 30 Hz.

3.3.2.4. Experimental procedure

Participants seated at 60 cm of a 24”-Full HD monitor in which the stimulus was displayed. A recording was taken from each participant during the complete session with a HD webcam placed on the upper side of the monitor. The experimental design followed in this study was based on Broch-Due et al. (2018) and Samant et al. (2017) methodology. An overall scheme of the experimental design is shown in Figure 8. Before the presentation of the stimulus, a baseline measure of the facial expression of each participant was conducted for 10 seconds while the subject looked at a white screen with a centred black cross. To minimised expression biases, this baseline recording was used as individual calibration. Then, the 66 images selected to be used in the study from OASIS and FRIDa databases were randomly displayed in a monodic order. Each image was shown in 700px size for 5 seconds. The same white screen with a black cross was displayed for 3 seconds between target images for emotion attenuation. To prevent boredom, 30 second breaks were planned after groups of 10 target images. During the experimental session, the subject was alone in the laboratory setting to avoid an emotion dampening caused by the presence of a researcher.

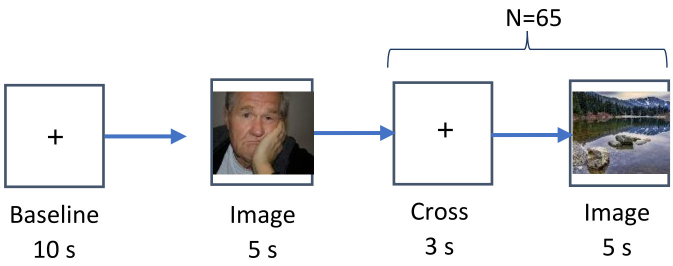


Figure 8. Scheme of the experimental procedure followed to evaluate the emotional response elicited by evocative images.

3.3.2.5. Data analysis

Considering that OASIS and FRIDa images were differently rated during their validation studies, "positively valenced" images were considered when valence ratings were over or equal to 4.5 in OASIS (from a 7-point scale) and 50 in FRIDa (from 100-unit Visual Analogue Scale). Contrary, an image was labelled as "negatively valenced" when valence ratings were below 4.5 in OASIS and below 50 in FRIDa.

Based on Stöckli et al. (2018) the following considerations was taken into account to analyse FaceReader's results. An image was labelled as "positively valenced" when the highest value of all emotions measured corresponded to happy. Similarly, an image was labelled as "negatively valenced" when the highest value of all emotions was obtained for angry, sad, disgusted, or fear. Surprise, contempt, and neutrality were not considered for valence categorisation. Similar to the section 3.3.1. of this dissertation, FaceReader's performance was calculated as precision, recall, F1 and accuracy.

3.3.3. Recognition of the emotional response elicited by real food products

3.3.3.1. Participants

A total of 50 children from 5 to 12 yrs (54% boys, 46% girls) with a mean age of 8.0 $\pm$ 2.0 yrs were recruited from AZTI's database. To be eligible to participate in the study, parents signed an informed consent before the experimental session began. The participants aged below 12 yrs gave oral consent to participate in the study, while children aged 12 yrs provided written consent. The study complied with the principles established by the Declaration of Helsinki and the CEISH, the Basque Country University's Ethical Committee, approved the study protocol. The results of five children were discarded due to low quality.

3.3.3.2. Samples

Two samples with different texture, one liquid and one solid (Figure 9) were used in this study. Both food products were designed in AZTI's facilities from apple juice and were developed to have the same colour and odour. These samples were selected to evaluate FaceReader's recognition ability for the emotions elicited by food samples that could require chewing actions or not. The portion of each sample evaluated in the study was 16 g per sample.

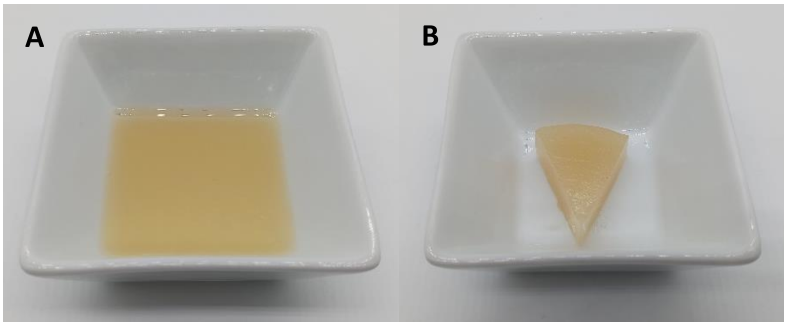


Figure 9. Samples with different texture evaluated in the study. A: liquid. B: solid.

3.3.3.3. Automated facial expression software

FaceReader 8.0 measured changes in the facial expressions of each participant during the session. Data was collected at a sampling rate of 30 Hz.

3.3.3.4. Experimental procedure

A HD webcam placed over the table that was used for the sensory testing recorded the facial expression of each participant during the experimental session. Each participant performed one session individually. After explaining the experimental procedure to the child, the webcam recorded a baseline measure of the subject’s facial expression for 10 seconds while the child looked at a sample not related to the study (an example) placed over the table. To minimise expression biases, this baseline measure was used as individual calibration. Afterwards, a researcher placed the sample on the table and the subject observed it with no time restrictions. Afterwards, children were asked to rate how much they liked the sample with a 7-point hedonic scale anchored at 1=”extremely disliked” and 7=”extremely liked”. The procedure was then repeated with the second sample. All participants firstly evaluated the liquid and then the solid product. During the experimental session, the subject was alone in the laboratory setting to avoid an emotion dampening caused by the presence of a researcher.

3.3.3.5. Data analysis

During the experimental session, one researcher marked as an event the exact moment in which each participant looked at each sample for the first time. The basic emotions elicited by both products were analysed for the first three seconds after this event and the emotional response was computed as valence. Similar to the protocol described in section 3.3.2.5., a facial expression was labelled as “positively valenced” when the highest value of all emotions measured during the observation of a sample corresponded to happy. Similarly, an expression was labelled as “negatively valenced” when the highest value of all emotions measured during the observation of a sample was obtained for angry, sad, disgusted, or fear. Surprise, contempt, and neutrality were not considered for valence categorisation.

Due to the lack of standardised reference material during this study, the liking ratings provided by the children were considered as an indicator of the pleasantness evoked by the food samples. Student’s t test was performed on liking ratings to identify significant differences between samples. Principal Component Analysis (PCA) was performed to graphically visualise the interaction between the samples, the emotions measured, and liking. Similar to section 3.3.1. and 3.3.2., FaceReader’s performance on the evaluation of the emotional valence elicited by real food samples was calculated as precision, recall, F1 and accuracy. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.4. Applicability of combined behavioural and physiological measures in the study of emotions elicited by food

3.4.1. Participants and samples

This work was conducted simultaneously with the study focused on the applicability of the emoji-based tool with real food samples (section 3.2.2. of this dissertation). Therefore, the same group of 50 schoolchildren and the six texture-modified samples were tested in this work. For a complete description of the group of participants and the food products involved in the study, see sections 3.2.2.2. and 3.2.2.3. The results of five children were discarded due to low quality.

3.4.2. Equipment

A HD webcam placed over the table that was used for the sensory tasting recorded the facial expression of each participant during the session. Additional cameras were hidden in front of the participant's face at -45º (left side), 0º and 45º (right side) as well as over the sensory booth to capture the overall scene. The FaceReader software (version 8.0, Noldus Information Technology, Wageningen, The Netherlands) measured changes in the facial expressions of each participant during the session as AUs and basic emotions. Data was collected at a sampling rate of 30 Hz. During the session, Shimmer3 GSR+ (Shimmer, Dublin, Ireland) monitored the skin conductance response (SCR) of each participant as an indicator of the emotional activation or arousal. To measure SCR, a researcher placed two Velcro-strap electrodes on proximal phalanges of index and middle fingers, on the non-dominant hand of the subject. Data was collected at a sampling rate of 128 Hz and processed by iMotions' software suite (version 8.0, iMotions, Inc., Copenhagen, Denmark).

3.4.3. Experimental procedure

Each participant performed one session individually. To minimise baseline differences in skin conductance among subjects, children cleaned their hands with water and non-alcoholic soap before the experimental session began. Afterwards, each participant sat comfortably, and a researcher placed the Shimmer device on the non-dominant hand. After explaining the experimental procedure to the child, the webcam recorded a baseline measure of his/her facial expression for 10 seconds. To minimise expression biases, this baseline measure was used as individual calibration. In addition, based on Braithwaite et al. (2013) and Dawson et al. (2000), each subject was exposed to an arousing task (i.e., a demanding arithmetical task appropriate for the age of the children) to obtain a theoretical maximum of skin conductance response induced by an exciting event. This task allowed us to establish a range of skin conductance response for each participant in which 0 was a basal measure and 100 corresponded with the theoretical maximum. Changes obtained in skin conductance response during the experiment were then expressed as a relative measure for each participant. After the arousing event, a researcher placed one sample on the table in front of the child who performed four sensory tasks with no time restrictions: (i) observation, (ii) olfaction, (iii) manipulation with a spoon (for liquid samples and T6) or the fingers (for T7.1 and T7.2), and (iv) consumption with a spoon (for liquid samples and T6) or the fingers (for T7.1 and T7.2). Once that the sample was tasted, children answered a question regarding how much they liked it by using a 7-point hedonic scale anchored at 1="extremely disliked" and 7="extremely liked". All subjects evaluated the samples following the same order from T1 to T7.2

samples to make the recognition of texture differences easier for the children. To prevent social interaction with the researchers during the evaluation of the products, each child was alone in the sensory booth.

3.4.4. Data analysis

With the help of the cameras located throughout the sensory booth, during the sessions one researcher marked in iMotions' software suite the exact moment in which each participant performed four events or behaviours: i) first look, ii) start of a close smell, iii) first touch with the spoon or the fingers, and iv) food placed in the mouth. This approach was performed to provide a context to each measure. After the sessions, the events marked were checked and data regarding the AUs activation and the basic emotions displayed were analysed only for the first three seconds after each event. Contrary, changes in SCR were analysed in the range of 2000-5000 ms due to the existing delay between the event and the SCR regulation (Dawson et al., 2000). In this study, the analysis of a short period of time (3000 ms) after each event was chosen to prevent overlapping among events since the sensory tasks were conducted with no time restrictions for ecological validity. Averages of the baseline-corrected intensity of AUs and basic emotions activation as well as of the changes in SCR were calculated every 500ms, leaving to 6 time-ranges. For this work, the facial expressions displayed during the first time-range defined in this study, 0-500 ms, were considered an unconscious or implicit response, while the expressions displayed during the rest of the time-ranges established, from 500 ms to 3000 ms, were considered a conscious or explicit response. PCA was carried out on average data to graphically visualised the sample configurations and the sample discrimination reached with the combined methodology used. XLSTAT 2019.1.2 software (Addinsoft, Boston, USA) was used for the data analysis. Effects showing a *p*-value equal or lower than 0.05 were considered significant.

3.4.4.1. PCA with AUs data

The 20 AUs measured by FaceReader 8.0 were considered for the PCA conducted on the observation, olfaction, and manipulation data. However, in the consumption task only the AUs that are not influenced by the movement of facial muscles during food consumption were considered. On this regard, according to a literature review (Epstein & Paluch, 1997; Gamboa et al., 2019; Hanawa et al., 2008; Shiratori et al., 2021; Takada et al., 1994) the AUs located on the middle and lower parts of the face were avoided (i.e., AU09, AU10, AU12, AU14, AU15, AU17, AU18, AU20, AU23, AU24, AU25, AU26, AU27).

The categorisation of AUs into positive, neutral, and negative expressions was performed according to other previous studies (Ekman et al., 2002a; Soussignan & Schaal, 1996; Zeinstra et al., 2009). Therefore, the following AUs were considered as negatively valenced: AU01 (*inner brow raiser*), AU02 (*outer brow raiser*), AU04 (*brow lowerer*), AU09 (*nose wrinkler*), AU10 (*upper lid raiser*), AU15 (*lip corner depressor*), AU20 (*lip stretcher*), AU24 (*lip pressor*), AU25 (*lips part*), and AU43 (*eyes closed*). On the other hand, the AU12 (*lip corner puller*) as well as the combination of AU06 (*cheek raiser*) + 12, AU12 + 25 and AU24 + 25 were considered as positive. Additionally, AU06, AU17 (*chin raiser*) and AU18 (*lip pucker*) were included as neutrally valenced.

3.4.4.2. PCA with basic emotion data

PCA was only conducted on the basic emotion data obtained during the observation, olfaction, and manipulation. It was not performed with the consumption data, since the codification algorithm of FaceReader 8.0 for all basic emotions rely on the identification of AUs located throughout the face, part of which can be altered with the movement of facial muscles during the oral processing actions (Loijens & Krips, 2019).

4. Results & Discussion

4.1. Study 1. The evaluation of children’s understanding of emoji

4.1.1. Preselection of the emoji

From the 41 facial emoji initially included a consensus among all participants was reached on the valence categorisation of 26 icons (Table 4). From those 26 facial emoji, 12 were classified by the children as “positive”, 4 as “neutral” and 10 emoji as “negative”. The other emoji evaluated in this pre-test were discarded due to a lack of consensus in valence categorisation.

Table 4. Valence categorisation of the initial set of facial emoji into positive, neutral, and negative categories. (*) Excluded emoji for which consensus could not be reached among the children that participated in this task. In the "Excluded emoji" group, the non-consensus categories for each emoji are described (in brackets) as: P = positive; Ne = neutral; N = negative; D = I do not know.

Positive emoji

- Face savouring delicious food
- Face throwing kiss
- Face with stuck-out tongue
- Face with stuck-out tongue and winking eye
- Face with tears of joy
- Grinning face
- Grinning face with smiling eyes
- Smiling face
- Smiling face with heart-shaped eyes
- Smiling face with open mouth and smiling eyes
- Smiling face with smiling eyes
- Winking face

Negative emoji

- Angry face
- Confounded face
- Crying face
- Disappointed face
- Face with cold sweat
- Loudly crying face
- Persevering face
- Pouting face
- Sad pensive face
- Worried face

Neutral emoji

- Face with wide open eyes
- Expressionless face
- Neutral face
- Sleeping face

Excluded emoji *

- Confused face (Ne, D)
- Disappointed but relieved face (Ne, N)
- Distraught face (N, D)
- Face screaming in fear (N, D)
- Face with open mouth and cold sweat (Ne, N, D)
- Face with stuck-out tongue and tightly closed eyes (P, N)
- Face without mouth (D)
- Fearful face (Ne, N)
- Frowning face with open mouth (Ne, N)
- Grimacing face (Ne, N, D)
- Relieved face (P, Ne)
- Smiling face with sunglasses (P, Ne)
- Smirking face (P, Ne, D)
- Unamused face (Ne, N)
- Weary face (Ne, N)

4.1.2. Development of emotion word list

The 26 preselected emoji were afterwards showed monadically to the children and the spontaneous words provided as descriptions of the sentiment or emotion conveyed by each emoji were recorded. The complete list of the terms is shown in Table 5.

Table 5. Spontaneous terms associated with the emoji during the emotion words development task (N = 20 children). Descriptions correspond to the emoji's Unicode name as found in Emojipedia. [a] Terms that emerged in the three groups of children that participated in the word development task (section 3.1.1.). [b] Terms that did not emerge in the three groups that participated in the word development task (section 3.1.1.) (only in one or two out of the three).

Emoji	Description	Emotions terms given by children
	Angry face	Very angry [a], angry [b]
	Confounded face	Crapping [a], disgusted [a], shivering [b]
	Crying face	Sad [a], crying with sadness [a], a bit sad [b]
	Disappointed face	A bit sad [a], bored [b], lonely [b], feels bad [b]
	Expressionless face	Serious [a], normal [b], tired [b], it does not want to talk anymore [b]
	Face savouring delicious food	Happy [a], hungry [b], it is thinking of delicious food [b]
	Face throwing kiss	Blowing a kiss [a], affectionate [a], happy [b], loving [b], good [b], flirting [b]
	Face with cold sweat	Sweating [a], it has been doing sport [b], tired [b], guilty [b], regretful [b]
	Face with stuck-out tongue	Happy [a], joking [a], smiling [b], funny [b], playful [b]
	Face with stuck-out tongue and winking eye	Joking [a], playful [b], happy [b], smiling [b], cool [b]
	Face with tears of joy	Extremely happy [a], crying with joy [a], laughing [b]
	Face with wide open eyes	Scared [a], ashamed [a], surprised [b], neither good nor bad [b]
	Grinning face	Happy [a], smiling [a]
	Grinning face with smiling eyes	Very happy [a], happy [b], laughing [b]
	Loudly crying face	Extremely sad [a], crying [b]
	Neutral face	Serious [a], no comments [a], normal [b], ashamed [b]
	Pouting face	Extremely angry [a]
	Persevering face	Feels bad [b], angry [b], very sad [b], it is almost barfing [b]
	Sad pensive face	Sad [a], feels bad [b], almost crying [b], it has done something bad [b]
	Sleeping face	Sleeping [a], bored [a], snoring [b]

☺️	Smiling face	Happy [a], content [a], ashamed [b], normal [b]
😍	Smiling face with heart-shaped eyes	Loving [a], affectionate [b]
😄	Smiling face with open mouth and smiling eyes	Very happy [a], laughing [b]
😊	Smiling face with smiling eyes	Happy [a], ashamed [b], smiling [b]
😉	Winking face	Happy [a], smiling [a], content [b], feels good [b], funny [b], cool [b]
😟	Worried face	Sad [a], worried [b]

Differences were observed in the variability of words provided by the children that participated in the emotion words development task. On average, considering all the words collected from the three age groups of children, 20 words were provided by children from 6-7 yrs; 23 words by children from 8-9 yrs; and 27 words by children from 10-12 yrs. Interestingly, child-friendly terms were used to describe certain emotions, such as "no comments" which was given to describe "indifference" or "neutrality". Only the emotion words that were repeated along the three focus groups (marked with [a] in Table 5) were used to evaluate facial emoji's meaning to obtained a short list with no more than 20-25 terms as recommended by (Schouteten et al., 2019). Due to the lack of a main emotional meaning, *face with cold sweat* (😓) and *persevering face* (😣) were discarded.

4.1.3. *Evaluation of facial emoji's meaning*

Once that the child-friendly emotion lexicon was developed, the dimensional and semantic meaning of the emoji was measured in two contexts: a free-of-context situation and in a food-related context (see section 3.1.2.4.). As reported in 3.1.2.1., the meaning of 6 additional emoji was also evaluated. Table 6 shows the characteristics of the two populations of children that participated in the study.

Table 6. Summary information about the scholars that participated in both surveys. No significant differences were found among both populations ($p>0.05$ in Fisher's exact test).

	Free-of-context	*Food-related context*	*p value*
Participants	154	158	
Gender (%)			0.816
Boys	52	51	
Girls	48	49	
Non-binary	0	0	
Age (years old) (%)			0.865
6-8	35	38	
9-12	65	62	
Among 6-8 yrs:			
Daily access to a smartphone or tablet (%)			0.532
Yes	30	24	
No	70	76	
Frequency of use of emoji in everyday life (%)			0.230
Frequently	28	21	
Sometimes	48	35	
Never	24	44	
Among 9-12 yrs:			
Daily access to a smartphone or tablet (%)			0.814
Yes	64	62	
No	36	38	
Frequency of use of emoji in everyday life (%)			0.980
Frequently	49	51	
Sometimes	41	40	
Never	10	9	

4.1.3.1. Dimensional meaning

4.1.3.1.1. Evaluation in a free-of context situation

Valence and arousal dimensions were determined in a free-of-context situation for each of the 30 emoji (Figure 10A).

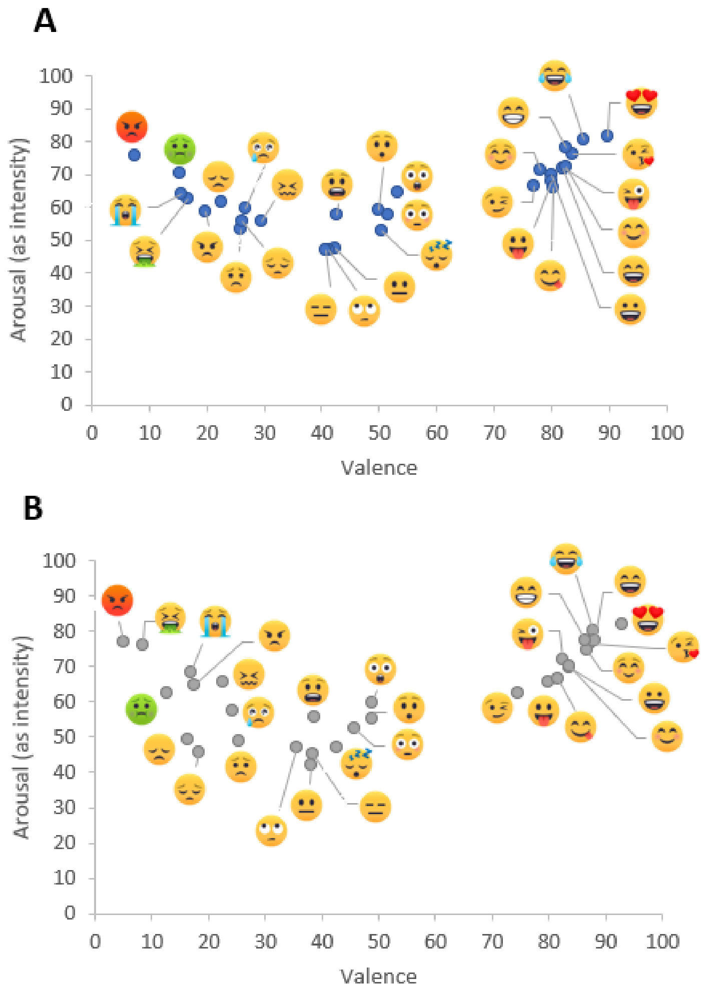


Figure 10. Valence and arousal biplot for the 30 emoji evaluated in the study with a 100-units Visual Analogue Scale (VAS). A: free-of-context situation (N = 154 children). B: evoked food-related context (N = 158 children).

The range of valence ratings obtained was between 8 and 90 in the 100-units VAS anchored at "0-Negative" and "100-Positive". According to the valence categorisation described in section 3.1.2.5., 12 emoji were classified as positive, 8 emoji as neutral and 10 emoji as negative. Emoji that included a smile, smiling eyes or heart-shaped eyes (e.g., ,  and ) were frequently considered as positively valenced, while emoji with a frown, tears, X-shaped eyes, or depressed lips (e.g., 😠, 😢, 😖 and 😞) were mainly considered as negatively valenced. Surprised-like expressions (wide-open eyes, raised eyebrows and open mouth (e.g., 😳 and 😨)) and expressionless features (e.g., 😐 and 😑) characterised neutral emoji. A narrower range of ratings was obtained for the arousal dimension, measured as intensity of the emotion conveyed by the emoji. Scores ranged from 47 to 82 in the 100-units VAS anchored at "0-Low intensity" and "100-High intensity". According to the arousal categorisation described in section 3.1.2.5., 14 out of the 30 emoji were considered as active and 16 as neutral. None of the emoji were categorised as relaxed. In our study, open mouth smiles and smiling eyes were perceived as arousing as well as the inclusion of distinctive features such as tears (e.g., *loudly crying face* (😭)) or colours (e.g., *pouting face* (😡) and *nauseated face* (🤢)).

4.1.3.1.2.Effect of a food-related context

The evocation of a food-related context (Figure 10B) before the evaluation of each emoji changed their dimensional meaning in comparison with a free-of-context situation (Figure 10A). Significant differences between free-of-context and food-related context situations were found for both valence (p<0.001) and arousal (p<0.001) ratings. The food-related context made the emoji more extremely valenced (Figure 11A). While positive emoji were considered more positively valenced in the food-related context (p<0.001) (e.g., *smiling face* (😊)), neutral (p<0.001) (e.g., *sleeping face* (😴)) and particularly negative (p<0.001) emoji (e.g., *face with open mouth vomiting* (🤮)) were significantly perceived as more negative in the food context than in the free-of-context situation.

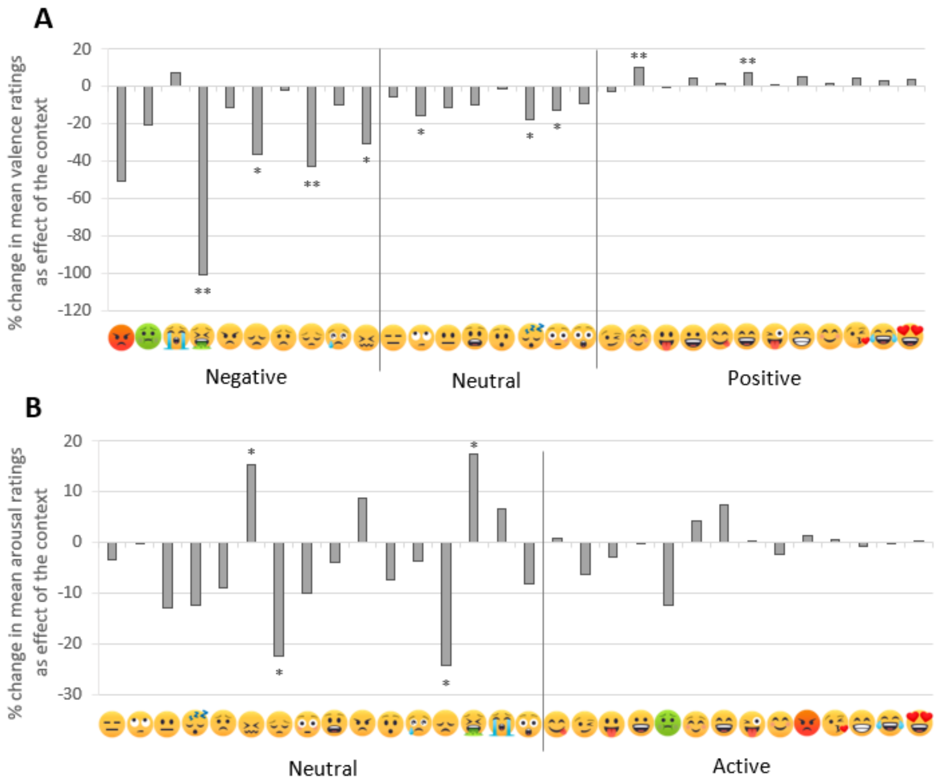


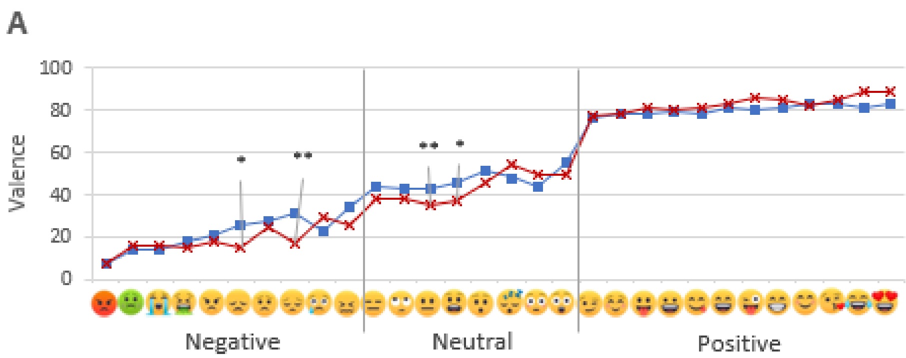
Figure 11. Percentage of change in the dimensional meaning of each emoji due to the context of evaluation. The data shown are the results obtained in the food-related context evaluation in comparison with a free-of-context situation. A: changes in valence ratings. B: changes in arousal ratings. Emoji are showed according to the mean scores for valence and arousal, respectively. Vertical lines are displayed to differ negative, neutral, and positive emoji in valence plot as well as neutral and active emoji in arousal plot * p<0.05. ** p<0.01 in Student's t test.

Contrary to valence, there was no clear tendency on the effect of the food-related context on the arousal perception of the emoji (Figure 11B). No significant effect of the food-related context was noticed in neutral (p=0.175) or active emoji (p=0.690) as a group. However, 4 out (*confounded face* (😖), *sad pensive face* (😔), *disappointed face* (😞) and *face with open mouth vomiting* (🤮)) of the 30 emoji specifically differed in arousal because of the food-related context.

4.1.3.1.3.Effect of gender

Children's gender influenced the dimensional meaning of the emoji in both situational contexts. Results regarding the valence dimension are shown in Figure 12 (A and B).

Lower valence scores were provided by the girls ($p<0.001$) in both contexts. In the free-of-context evaluation (Figure 12A), significant differences in dimensional meaning between boys and girls were found for negative ($p<0.05$, respectively) and neutral ($p<0.05$, respectively) emoji; however, the evocation of a food-related context (Figure 12B) focused the differences between boys and girls only on the neutral icons ($p<0.05$, respectively). No significant differences were found in arousal ratings (Figure 12C and 12D) between gender groups ($p>0.05$).



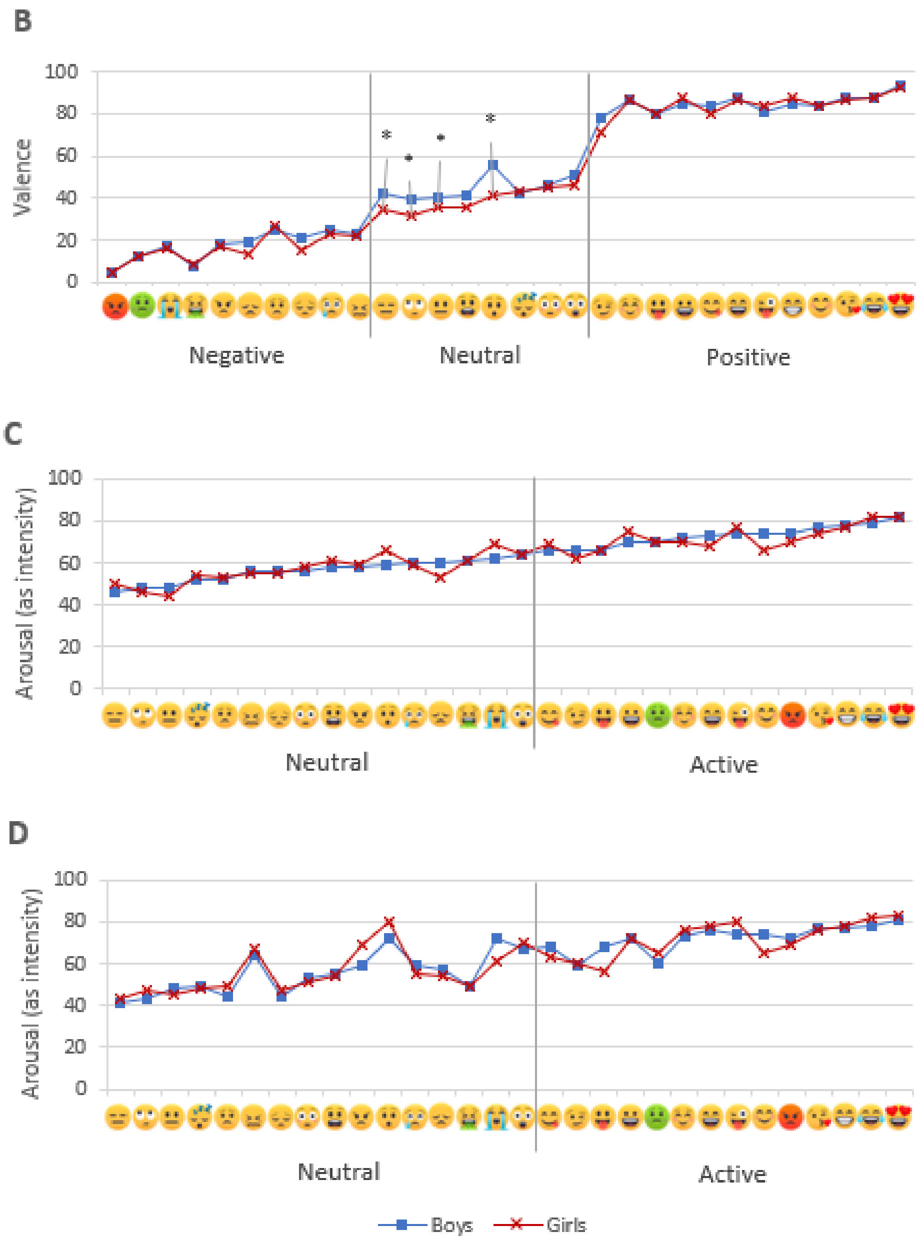
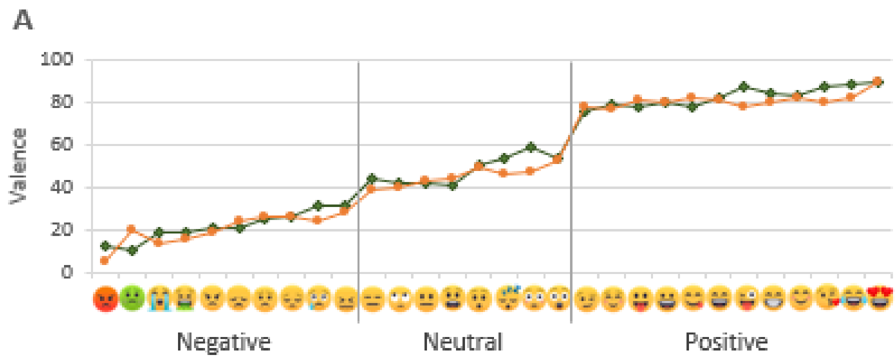


Figure 12. Dimensional meaning of the emoji provided by the children considering gender groups. A: valence mean ratings in the free-of context situation. B: valence mean ratings in the food-related context. C: arousal mean ratings in the free-of context situation. D: arousal mean ratings in the food-related context. Vertical lines are displayed to differ negative, neutral, and positive emoji in valence figures (A and B), as well as neutral and active emoji in arousal figures (C and D). * p<0.05. ** p<0.01 in Student's t test.

4.1.3.1.4.Effect of age

Two age groups were established to examine the effect of this variable on the meaning of the emoji. The age of the participants influenced the perception of the dimensional meaning of the emoji in both situational contexts (Figure 13).

No significant differences were found in valence ratings (Figure 13A and 13B) between the age groups (6-8 yrs and 9-12 yrs) (*p*>0.05). Nevertheless, significant differences were obtained in arousal ratings (Figure 13C and 13D) between the age groups in the two situational contexts evaluated. Older children (9-12 yrs) rated the emoji as significantly less arousing than their younger peers (6-8 yrs), result specially obtained for the active emoji (*p*<0.001).



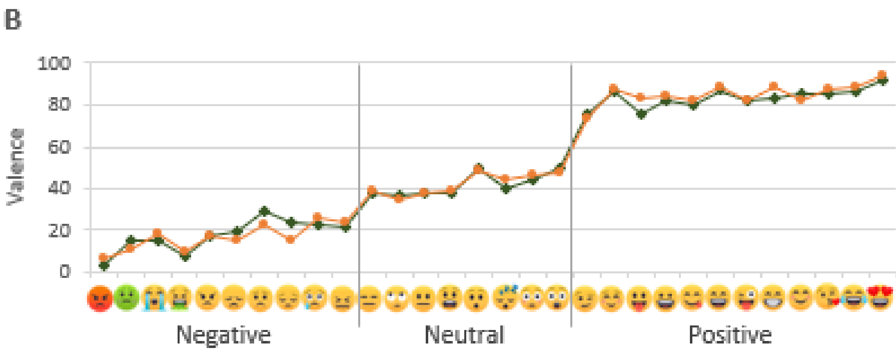


Figure 13. Dimensional meaning of the emoji provided by the children considering age groups. A: valence mean ratings in the free-of context situation. B: valence mean ratings in the food-related context. C: arousal mean ratings in the free-of context situation. D: arousal mean ratings in the food-related context. Vertical lines are displayed to differ negative, neutral, and positive emoji in valence figures (A and B), as well as neutral and active emoji in arousal figures (C and D). * p<0.05. ** p<0.01 in Student's t test.

4.1.3.2. Semantic meaning

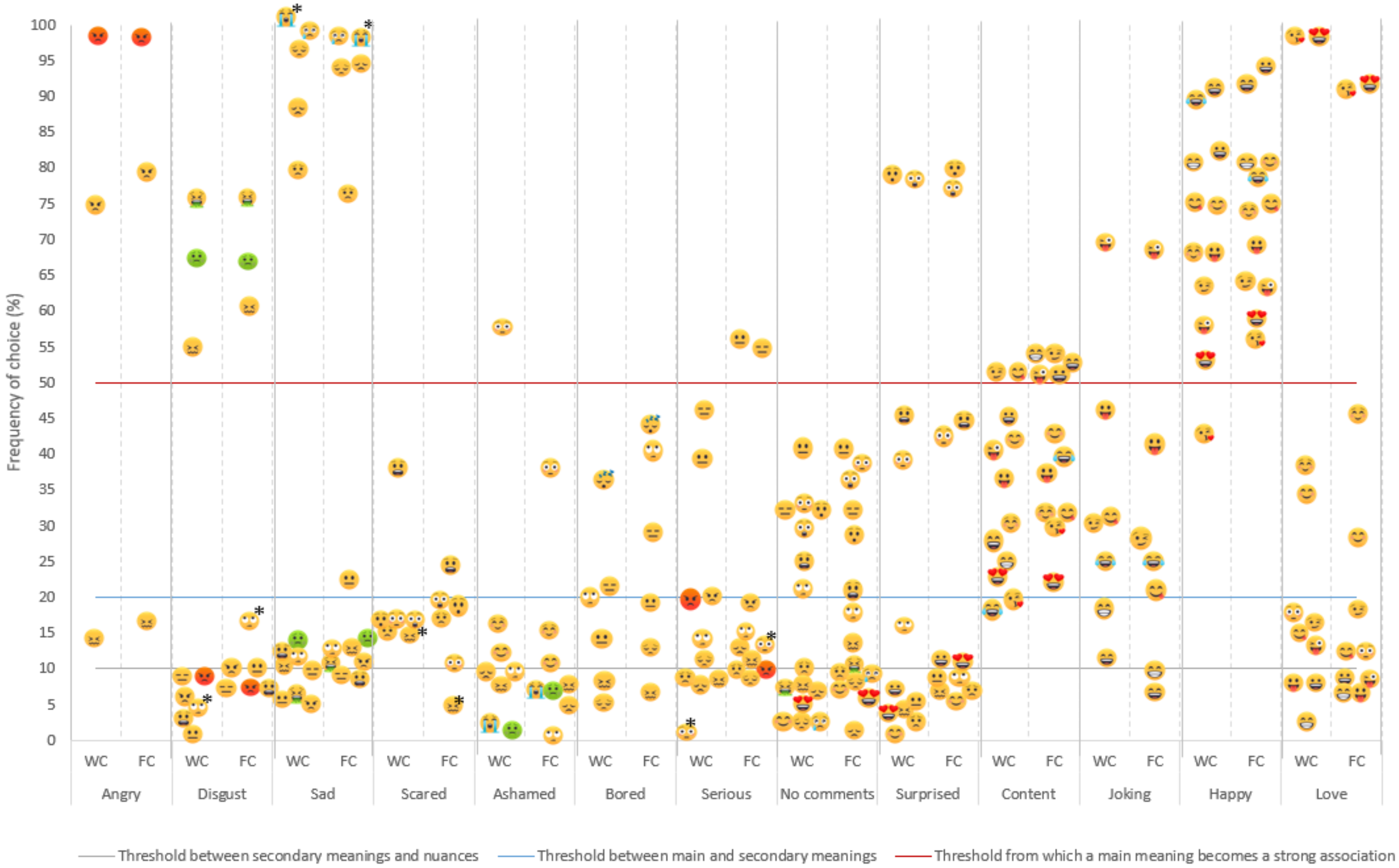
4.1.3.2.1.Evaluation in a free-of context situation

The results obtained regarding the semantic meaning of the emoji in a free-of-context situation are shown in Figure 14. According to Jaeger & Ares (2017), categories with an average frequency of use over 20% of the participants were considered as the main meaning for each emoji. Among them, strong associations were established for frequencies over 50%. Additionally, emotion word categories chosen over 10% of participants were also considered and were defined as secondary meanings for each emoji.

The distribution of emoji in the plot suggested that there was a strong association between the happy emotion word category and the positively valenced emoji. The content and joking emotion word categories were also associated with the positively valenced emoji and were identified as a main meaning. On the contrary, the dispersion of emoji throughout the frequency span for the love category suggested that this emotion word category was more discriminative for positive emoji.

Interestingly, the distribution of negatively valenced emoji in the plot suggested that the angry, disgust and sad emotion word categories were strongly associated with specific emoji (e.g., *angry face* (😠) and *pouting face* (😡) with angry category), but also provided secondary meanings to other negative emoji (e.g., *confounded face* (😖) and *face with open mouth vomiting* (🤮) with angry category).

The scared, ashamed, bored, serious, no comments and surprised categories were considered as the main meaning for neutrally valenced emoji. These categories also provide secondary meanings for other emoji independently of their valence categorisation. In addition, strong associations were established between the surprised category and *astonished face* (😲) and *surprised face* (😯) as well as between ashamed and *face with wide open eyes* (😳).



Frequency of choice (%)
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC WC FC
Angry
Disgust
Sad
Scared
Ashamed
Bored
Serious
No comments
Surprised
Content
Joking
Happy
Love
Threshold between secondary meanings and nuances
Threshold between main and secondary meanings
Threshold from which a main meaning becomes a strong association

Figure 14. Frequency of choice (%) for which each emotion word category was associated with each emoji in a without context situation (WC) (N=154 children) and in a food-related context (FC) (N=158 children). Grey line represents the threshold (10%) between nuances and secondary meanings. Blue line represents the threshold (20%) between secondary and mean meanings. Red line represents the threshold (50%) from which a main meaning is considered to have a strong association with an emoji. Dotted-vertical lines differed the results obtained for both contexts. * Emoji with a different frequency of choice between both contexts for an emotion word category (p<0.05) according to the Fisher's exact test.

4.1.3.2.2.Effect of context

The main semantic meaning of the emoji remained stable when the food-related context (see section 3.1.2.4.) was evoked (Figure 14). The only exception was obtained for the *loudly crying face* (😭) emoji for which the sad meaning was significantly reduced ($p<0.05$) when the food-related context was evoked. In addition, the evaluation of the emoji in the food-related context induced a change in the secondary meanings of 3 out of the 30 emoji. As shown in Figure 14, the evocation of the food-related context induced an increase in the emotional connotation of disgust for *face with rolling eyes* (🙄) and serious for *face with wide open eyes* (😳) as well as a decrease of the scared meaning of *confounded face* (😖).

Additionally, Correspondence Analysis (CA) were performed to deepen on the effect of context of the semantic meaning of the emoji (Figure 15).

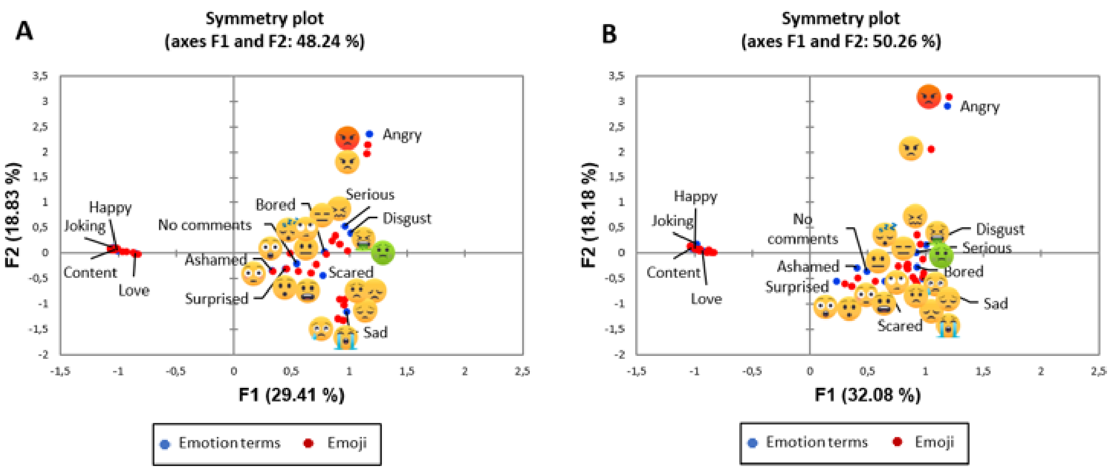


Figure 15. Symmetry plots representing the associations established between the emoji and the emotion terms used in this study in two situational contexts. A: results from all the participants in a free-of-context situation. B: results from all the participants in a food-related context. In both plots, positively valenced emoji were not labelled because they could not be discriminated due to overlapping.

The symmetry plot that represents the emoji and emotion word categories in the food-related context (Figure 15B) showed a similar trend to the one obtained from the free-of-context data (Figure 15A). In both plots the first factor was associated with valence since positive and negative emoji were placed in right and left side of the quadrant as well as neutral emoji were located between them. The second factor did not seem to relate to arousal since active emoji were placed on both upper and lower sides of the quadrant (e.g., see locations of *pouting face* () and *loudly crying face* () emoji). Instead, it seemed to relate to power. The power dimension is defined by appraisals of power or weakness regarding feelings of control (control vs submission) (Gillioz et al., 2016; Sick, Monteleone, et al., 2020). Items associated with anger (high in power) were placed on the upper side whereas the emoji and lexicon related to sadness (low in power) were located on the lower side. Apart from this general trend, the evocation of the food-related context changed the location of specific emoji by decreasing the discrimination ability of sad items as well as increasing the differences between angry emoji.

4.1.3.2.3.Effect of gender

To explore the effect of gender on the semantic meaning of the emoji, additional CA were performed. The symmetry plots displayed in Figure 16 suggested that gender did not influence the semantic meaning of the emoji. Whatever the gender was, the distribution of the first and second factor followed the trend observed in the symmetry plots displayed with the data obtained from all the children (Figure 15), i.e., the first factor was related to valence and the second factor was associated with power. A similar distribution of items was obtained for both genders whatever the context of evaluation was. An exception was observed in boys for which the evocation of the food-related context increased the power perception of the *pouting face* (😡) emoji.

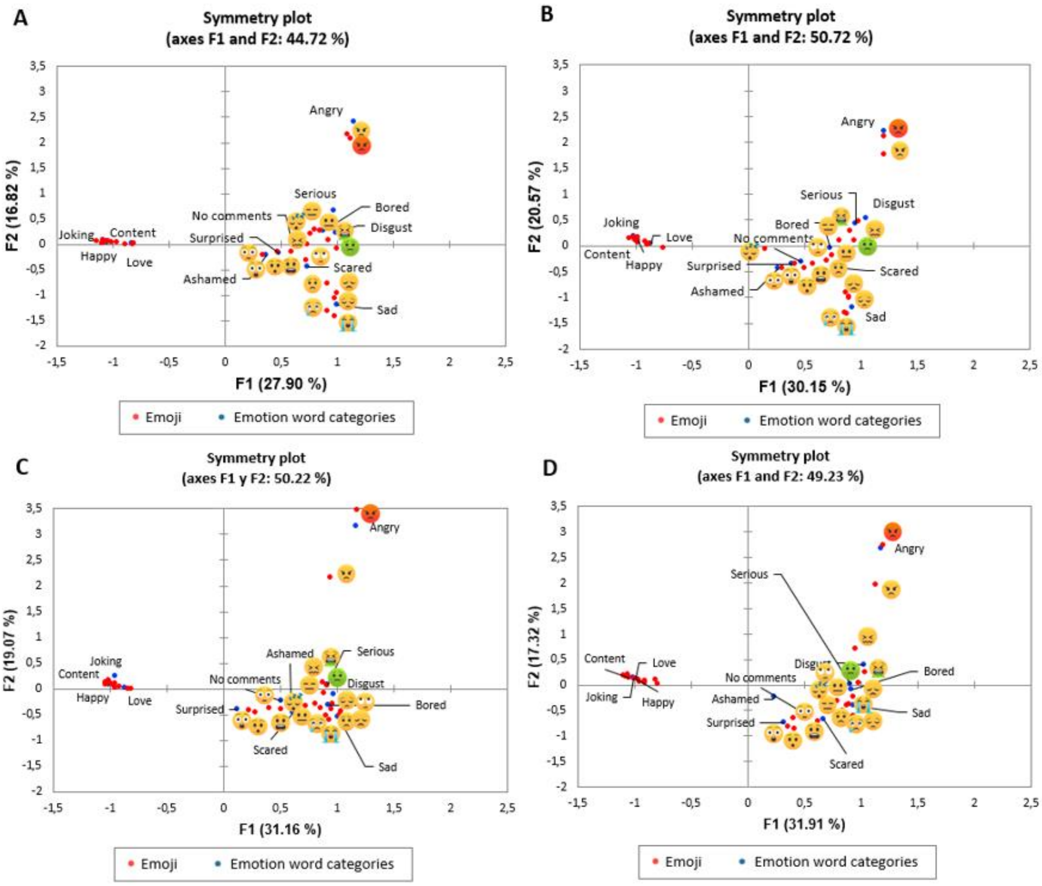


Figure 16. Symmetry plots representing the associations established by different gender groups between the emoji and the emotional terms used in this study in two situational contexts. A: results from the boys in the free-of-context situation. B: results from the girls in the free-of-context situation. C: results from the boys in the food-related context. D: results from the girls in the food-related context. In the plots, positively valenced emoji were not labelled because they could not be discriminated due to overlapping.

4.1.3.2.4. Effect of age

The age of the children influenced the semantic meaning of the emoji (Figure 17). The symmetry plots displayed in Figure 17 followed the same trend than the plots performed with the data obtained from all the participants. The first factor of the analysis was related to the valence dimension, while the second factor was associated with power. Positively valenced emoji were similarly located whatever the context and the age of the children was. On the contrary, differences were found on the power perception of negative emoji. In a free-of-context situation, older children (9-12 yrs) had more discrimination ability on sad items, while younger participants (6-8 yrs) better discriminated angry items. The power perception of the emoji did not change for the younger children (6-8 yrs) when the food-related context was evoked. Contrary, the discrimination ability of older participants (9-12 yrs) for sad items decreased whereas increased for angry items when the food context was induced.

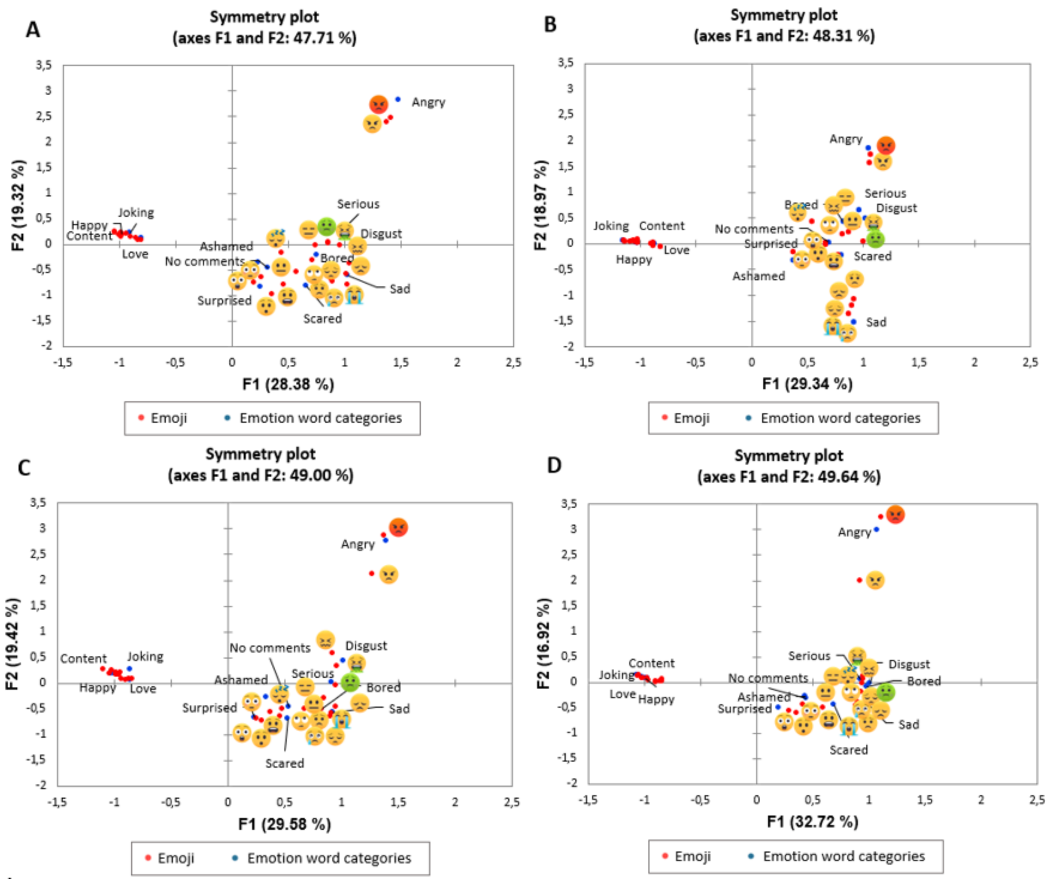


Figure 17. Symmetry plots representing the associations established by two different age groups between the emoji and the emotional terms used in this study in two situational contexts. A: results from the 6-8 yrs group in the free-of-context situation. B: results from the 9-12 yrs group in the free-of-context situation. C: results from the 6-8 yrs group in the food-related context. D: results from the 9-12 yrs group in the food-related context. In the plots, positively valenced emoji were not labelled because they could not be discriminated due to overlapping.

4.1.4. Discussion

This study evaluated the dimensional and semantic meaning that school-aged children give to facial emoji as well as the influence that age, gender, and the situational context of evaluation have on their perception. The pre-test developed allow us to identify a group of emoji that were similarly understood by all participants regardless of their age and gender as well as a list of child-friendly lexicon suitable to describe the emotion portrayed.

4.1.4.1. Dimensional meaning of the emoji (in the free-of context situation)

The valence span measured with 100-unit VAS was almost completely covered, but not the arousal dimension. The difficulties observed during the pre-test in the categorisation of valence was not unexpected, since other authors also reported difficulties during valence categorisation of emoji in studies conducted with adults (Jaeger et al., 2019; Jaeger & Ares, 2017) and children (Gallo, 2016).

The development of lexicon associated with the intensity of the emotion in the focus group (e.g., “happy” and “very happy”) highlighted the necessity to also cover the arousal dimension of the emoji to understand their dimensional meaning. Nevertheless, the narrow range of arousal scores obtained in the online survey and the lack of a group of relaxed emoji supported the idea that arousal is a complex concept. Difficulties in differing the specific group of relaxed emoji were also found in other studies developed with children aged 8-11 yrs (Schouteten et al., 2019) and pre-adolescents (Sick, Monteleone, et al., 2020).

The Correspondence analysis conducted on semantic data suggested that the arousal dimension was not among the first two dimensions that explained data variability. The power dimension, defined by appraisals of power or weakness (Gillioz et al., 2016), showed more relevancy than arousal. On this regard, our study pointed out that schoolchildren’s understanding of emoji was different from adults' perspective (Jaeger & Ares, 2017), for which valence and arousal were the dimensions that explained more data variability, and similar to the perception of pre-adolescents from 9-13 yrs (Sick, Monteleone, et al., 2020) for which valence and power were the dimensions that explained more data variability.

4.1.4.2. Semantic meaning of the emoji (in the free-of context situation)

The lexicon evaluated in this study was developed by the children because the use of participant's own words was recommended to make a verbal questionnaire more familiar (Gmuer et al., 2015; Jaeger, Lee, et al., 2017).

All positively valenced emoji evaluated in this study were associated with a short and fixed list of main and secondary meanings, what made them to be similarly understood. The overlapping obtained on positive emoji suggested that school-aged children were not aware of the graphical nuances of each emoji or that those differences did not have an emotional connotation for them. Another possible explanation might be that positive emotion word categories defined during the pre-test could have been lacking in variability and important emotions were missing. In this sense, school-aged children over 6 yrs perceived positively valenced emoji in the same manner as reported by Sick, Monteleone, et al. (2020) for preadolescents from 9-13 yrs. Those authors also reported overlapping in the semantic meaning of positive emoji when a longer list of 30 emotion terms based on literature was used.

On the contrary, negatively and neutrally valenced emoji were semantically different. The semantic definition of negative emoji with our list of child-friendly lexicon was consistent with previous studies with pre-adolescents (Sick, Monteleone, et al., 2020) and adults (Jaeger et al., 2019). Long lists of unrelated categories (over 6 categories) were used to describe certain neutral emoji (i.e.,

😳, 😐 and 🙄) suggesting that their graphical design was ambiguous. The ambiguity of neutral emoji perceived by school-aged children in this work was in line with the results reported in other studies with adults (Jaeger et al., 2019) and young children from 3 to 5 yrs (Fane et al., 2018). As suggested by Jaeger & Ares (2017) for adults, our findings pointed out that emoji which portray "basic" emotions, such as anger or disgust, could be easier to describe, while emoji that represent "less basic" emotions may be more difficult and, therefore, could be perceived as ambiguous by the children.

4.1.4.3. Effect of context

According to Prescott (2017), a context is needed to correctly identify an emotion through facial expressions, what we might extend to facial emoji. In this study we observed that the evocation of a food-related context before the evaluation of the emoji changed their dimensional and semantic meaning.

Regarding the dimensional inherent, no clear tendency was observed for the arousal, but the emoji became more extremely valenced in the context situation. A possible explanation could be based on Piqueras-fiszman & Jaeger (2014)'s discussion on the effect that the appropriateness of the context in the food domain has on the frequency of use of emotion terms. The food-related context induced in our study was a generally positive situation in which the participant shared a meal with his/her family on a weekend. Positively valenced emoji could have been perceived as appropriate in this situation and, therefore, they could be considered as even more positive than in a free-of-context situation. On the contrary, neutrally and negatively valenced could have been perceived as inappropriate for the evoked food-related context and consequently considered as more negatively valenced.

The evocation of a food-related context also significantly changed the semantic meaning of emoji. Most differences were obtained for secondary meanings, what pointed out that the main meaning of emoji would be stable regardless of the context of evaluation. Some of the emoji that significantly changed because of context were recently described as food-specific in another study developed with preadolescents from 9 to 13 yrs (Sick, Spinelli, et al., 2020) and considered to be frequently used by adults to express food experiences on Twitter (Vidal et al., 2016). If these emoji showed specificity for different food contexts, is not surprising to confirm that their meaning changed in our work when they were evaluated in a meaningful situation in comparison with a free-of-context experience. Changes in emotion responses related to the appropriateness of the context in the food domain were previously described in adults by other authors (Piqueras-fiszman & Jaeger, 2014; Spinelli et al., 2014) but not in children.

In addition, two emoji (🙄 and 😴) also evaluated in another study (Sick, Spinelli, et al., 2020) but not considered as food specific were differently perceived in our work because of context. These emoji might show food specificity in the food-related context evoked in this work, but not in the contexts previously evaluated. In this sense, as reported by Piqueras-fiszman & Jaeger (2014) for food products, our results may suggest that some emoji may not be appropriate for all situational contexts, but for specific situations.

4.1.4.4. Effect of gender

Results obtained in this study showed that participants' gender influenced the perception of the dimensional meaning of the emoji.

The effect of gender was observed in both situations evaluated (free-of-context and food-related context) on the valence perception of neutral emoji, being more positively considered by the boys of the study. Positively valenced emoji were

similarly perceived by both genders regardless of the context. This result is opposed to the findings reported by Sick, Monteleone, et al. (2020) who concluded that girls from 9 to 13 yrs discriminated positive emoji by the power dimension in comparison with boys. These differences between both studies might consist of the inclusion of a younger group of children in our work (6-8 yrs), which is characterised by lower granularity and limited capability to recognise facial expressions from photographs and cartoons (Durand et al., 2007).
Unlike the dimensional meaning, no significant effect of gender was found for the semantic meaning of emoji among school-aged children whatever the context of evaluation was. This lack of differences based on gender was opposed to the findings reported by other authors in studies with preadolescents (9-13 yrs) in a food-related context (Sick, Monteleone, et al., 2020) and with adults in a free-of-context situation (Jaeger et al., 2019).

4.1.4.5. Effect of age

Significant differences in the dimensional and semantic meaning of the emoji were obtained between the two age groups established in this study in both situational contexts.

Regarding the dimensional meaning, the higher arousing perception of the emoji reported by the younger group of children (6-8 yrs) compared to their older peers (9-12 yrs) in both situations, may have been influenced by familiarity. Younger children reported to have less access to mobile phones and use emoji less frequently in daily life in comparison with older participants. On this regard, low familiarity is associated with an increase in attention and also in arousal (Schomaker & Meeter, 2015).

In addition, significant changes were also observed in the semantic meaning of the emoji as an effect of the age of the participants. Our results suggested that older children (9-12 yrs) changed their perception of sad and angry emoji when a food-related context was evoked, while slight differences in angry emoji were only observed for young schoolchildren (6-8 yrs). These results were in accordance with Sick, Monteleone, et al. (2020) who observed that older preadolescents (12-13 yrs) had a greater discrimination ability for emoji and emotion categories than their younger peers (9-11 yrs). Facial expressions of happiness and sadness in photographs can be recognised from early stages of childhood (5-6 yrs), but other negatively valenced emotions, such as fear, anger or disgust, or neutrality may not be clearly recognised until 7-10 yrs (Durand et al., 2007). Even though no studies were found regarding the development of the recognition ability for facial emoji, Kolb et al. (1992) concluded that children below 8 yrs have poor ability to match facial expressions with emotions in cartoons.

Overall, conclusions regarding the effect of age should be considered with caution because over 60% of children that participated in Study 2 were between 9 to 12 yrs.

4.2. Study 2. Identification and applicability of food-specific emoji in studies with evoked food names and images

4.2.1. Identification of food-specific emoji

After the evocation of a varied selection of food contexts, emoji chosen by equal or over 20% of the participants to describe the emotion felt were considered as food specific. Among them, strong associations for a specific context could be identified for emoji selected by equal or over 50% of the participants. (Table 7).

Table 7. Specificity of facial emoji for seven food-related contexts evoked as written stimuli. Results are shown as the percentage of participants that selected each emoji for each specific situation. Descriptions correspond to the emoji's Unicode name as found in Emojipedia (Emojipedia, 2020). Emoji are listed according to the mean scores for valence in a food-related context obtained in Study 1 of this dissertation (section 4.1). Frequencies of use of the emoji ≥20% of participants appear in bold.

Emoji	Description	General context (%)	Refused (%)	Very disliked (%)	Disliked (%)	Neither liked nor disliked (%)	Liked (%)	Very liked (%)	p-value
Positive									
😍	Smiling face with heart-shaped eyes	**36**[b]	0[c]	0[c]	0[c]	1[c]	12[c]	**56**[a]	***
😂	Face with tears of joy	5[ab]	0[b]	1[b]	1[b]	0[b]	3[ab]	6[a]	***
😘	Face throwing kiss	9[b]	1[c]	0[c]	0[c]	0[c]	6[bc]	19[a]	***
😊	Smiling face with smiling eyes	19[b]	0[c]	1[c]	0[c]	2[c]	**30**[ab]	**35**[a]	***
😁	Grinning face with smiling eyes	**22**[b]	0[c]	1[c]	0[c]	1[c]	**29**[b]	**40**[a]	***
😜	Face with stuck-out tongue and winking eye	18[ab]	0[c]	1[c]	0[c]	1[c]	12[b]	**22**[a]	***
😄	Smiling face with open mouth and smiling eyes	**21**[a]	1[b]	1[b]	1[b]	1[b]	**28**[a]	**32**[a]	***
😋	Face savouring delicious food	**62**[a]	0[c]	1[c]	1[c]	1[c]	**39**[b]	**68**[a]	***
😀	Grinning face	**28**[a]	1[b]	1[b]	0[b]	2[b]	**32**[a]	**31**[a]	***
😛	Face with stuck-out tongue	**24**[a]	0[b]	1[b]	0[b]	2[b]	19[a]	**29**[a]	***

	Smiling face	19^{b}	0^{c}	1^{c}	0^{c}	4^{c}	**27**^{ab}	**34**^{a}	***
	Winking face	8^{abc}	1^{d}	1^{cd}	0^{d}	3^{bcd}	10^{ab}	12^{a}	***
Neutral									
	Astonished face	14^{a}	1^{b}	3^{b}	0^{b}	2^{b}	1^{b}	5^{b}	***
	Face with wide open eyes	9^{a}	1^{b}	8^{a}	1^{b}	10^{a}	3^{ab}	1^{b}	***
	Sleeping face	0^{a}	1^{a}	0^{a}	0^{a}	0^{a}	0^{a}	0^{a}	n.s.
	Surprised face	10^{a}	1^{b}	3^{b}	3^{b}	5^{ab}	1^{b}	3^{b}	***
	Anguished face	10^{a}	3^{b}	4^{ab}	3^{b}	3^{b}	2^{b}	1^{b}	**
	Neutral face	12^{bc}	4^{cd}	18^{b}	4^{cd}	**53**^{a}	3^{cd}	0^{d}	***
	Face with rolling eyes	14^{b}	2^{c}	13^{b}	5^{bc}	**28**^{a}	2^{c}	0^{c}	***
	Expressionless face	10^{bc}	6^{bc}	16^{b}	9^{bc}	**39**^{a}	2^{c}	0^{c}	***
Negative									
	Confounded face	**31**^{a}	**29**^{a}	**27**^{a}	**34**^{a}	4^{b}	3^{b}	0^{b}	***
	Crying face	5^{abc}	8^{ab}	12^{a}	12^{a}	1^{bc}	0^{c}	0^{c}	***
	Sad pensive face	6^{bcd}	10^{abc}	15^{a}	14^{ab}	4^{cd}	1^{cd}	0^{d}	***
	Worried face	10^{abc}	10^{ab}	18^{a}	18^{a}	3^{bcd}	0^{d}	1^{cd}	***

	Disappointed face	5 ^{cd}	10 ^{bc}	16 ^{ab}	19 ^{a}	8 ^{cd}	0 ^{d}	1 ^{d}	***
	Angry face	3 ^{cd}	**23** ^{a}	10 ^{bc}	11 ^{b}	1 ^{d}	0 ^{d}	0 ^{d}	***
	Face with open mouth vomiting	**68** ^{a}	**66** ^{a}	**25** ^{b}	**54** ^{a}	4 ^{c}	5 ^{c}	1 ^{c}	***
	Loudly crying face	8 ^{ab}	14 ^{a}	4 ^{bc}	10 ^{ab}	0 ^{c}	1 ^{c}	0 ^{c}	***
	Nauseated face	**62** ^{a}	**56** ^{a}	**32** ^{b}	**50** ^{a}	8 ^{c}	5 ^{c}	1 ^{c}	***
	Pouting face	3 ^{c}	**32** ^{a}	6 ^{bc}	14 ^{b}	2 ^{c}	1 ^{c}	0 ^{c}	***

Means in the same row with the same superscript are not significantly different at *p*>0.05 according to Sheskin test. ** *p*<0.01, *** *p*<0.001, n.s. not significant.

The evocation of different food-related contexts allowed us to identify 17 food-specific emoji out of the 30 evaluated. The results showed in Table 7 outlined that a larger number of positively valenced emoji were food specific rather than negative or neutral icons. The "general context" was associated with both positively and negatively valenced emoji. Among the food-specific emoji, strong associations for this situation were obtained for *face savouring delicious food* (😋), *face with open mouth vomiting* (🤮) and *nauseated face* (🤢). The "liked" and "very liked" contexts were related to most positive emoji and strong associations were established with *smiling face with heart-shaped eyes* (😍) and *face savouring delicious food* (😋) in the "very liked" situation. Negatively valenced emoji were chosen to describe the emotions elicited by situations related to dislike and deny eating. Among these, strong associations were established with *face with open mouth vomiting* (🤮) and *nauseated face* (🤢). Finally, three neutral emoji (*neutral face* (😐), *face with rolling eyes* (🙄) and *expressionless face* (😑)) were associated with the situational context in which a food product is neither liked nor disliked, context for which *neutral face* (😐) emoji specially had a strong association.

A hierarchical cluster analysis was performed to evaluate possible redundancies among the food-specific emoji identified (Figure 18). This analysis was carried out since, according to the results shown in Table 7, positively valence emoji could be applicable in the same food-related contexts. Additionally, in a previous work (Study 1 of this dissertation; section 4.1.3.) we observed that children perceived positive emoji dimensionally and semantically in the same manner. The dendrogram obtained (Figure 18) allowed us to identify two groups of redundant emoji among the positively valenced ones: i) *grinning face* (😀), *smiling face with* *open mouth and smiling eyes* (😄) and *grinning face with smiling eyes* (😁); as well as ii) *smiling face with smiling eyes* (😊) and *smiling face* (☺️).

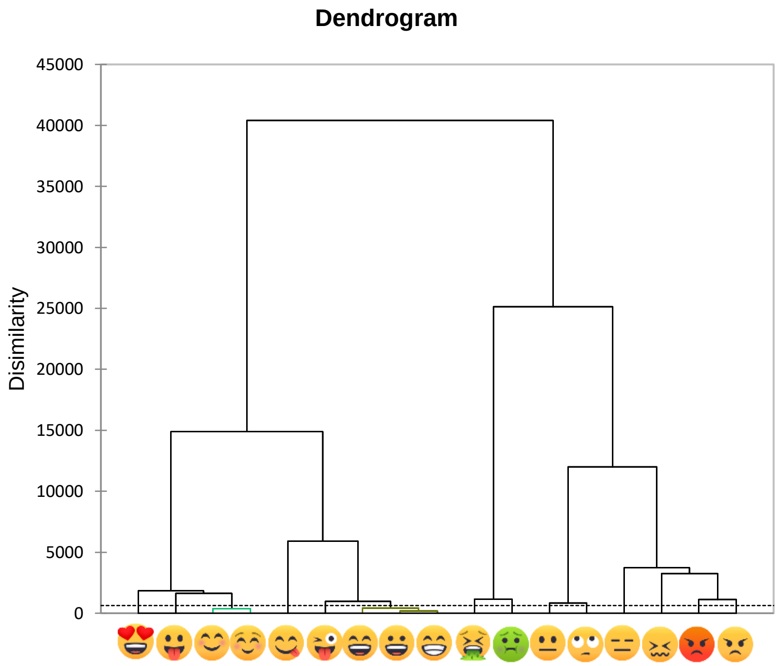


Figure 18. Identification of clusters among food-specific emoji. The dotted line represents the cut-off for dissimilitude among clusters.

No statistical differences were found on the frequencies of use of redundant emoji in any of the evoked contexts, so *grinning face with smiling eyes* (😁) and *smiling face with smiling eyes* (😊) were chosen to be included in further tests in representation of both cluster groups. Thus, 14 not-redundant food-specific emoji able to convey the emotions elicited by different evoked contexts were finally identified: six of these emoji were positively valenced (😍, 😊, 😁, 😜, 😋 and 😛), five of them were considered as negatively valenced (😖, 😠, 🤮, 🤢 and 😡) and the other three emoji were perceived as neutral (😐, 🙄 and 😑) by school-aged children.

4.2.2. Food-specific emoji's applicability for evoked food names and images

4.2.2.1. Expected liking

Six food samples were evoked in this study as food names and food images to elicit an emotional response in children. The expected liking reported by the participants for all the samples evoked is shown in Table 8.

Table 8. Liking scores obtained for each of the six food samples evoked as food names or images (N=95 children). Results are displayed as mean and standard deviation.

	Food names		Images		
Sample	**Mean**	**SD**	**Mean**	**SD**	***p* value**
Biscuit with chocolate chips	6.2 $^{a, A}$	1.3	5.1 $^{a, B}$	2.0	***
Cupcake	5.7 $^{ab, A}$	1.7	4.9 $^{a, B}$	2.1	**
Apple	5.4 $^{bc, A}$	1.5	5.2 $^{a, A}$	1.9	n.s.
Marie style biscuit	4.9 $^{cd, A}$	1.8	5.1 $^{a, A}$	1.9	n.s.
Cornflakes	4.4 $^{d, B}$	2.0	5.4 $^{a, A}$	1.7	***
Biscuit with dehydrated fruit	2.8 $^{e, B}$	1.8	5.3 $^{a, A}$	1.8	***
p value	***		n.s.		

Means in the same column with the same minor letter do not differ significantly (p>0.05) according to the Tukey's post hoc test. Means in the same raw with the same capital letter do not differ significantly (p>0.05) according to the Student's t test. ** p<0.01, *** p<0.001, n.s. not significant.

Liking scores ranged from 2.8 to 6.2 in the 7-point hedonic scale when the stimulus was evoked as a food name, but from 4.9 to 5.4 when it was evoked as an image. All samples were slightly or very liked, except the biscuit with dehydrated fruit that was expected to be disliked when it was evoked as a food name. Significant differences (p<0.001) on liking ratings were solely obtained when the samples were evaluated as food names. The most liked samples were the biscuit with chocolate chips and the cupcake; while the apple, the Marie style biscuit, and the cornflakes were medium liked. The evocation of the biscuit with chocolate chips and the cupcake as a food name increased their expected liking compared to the evocation of images (p<0.01, respectively). Contrary, the cornflakes and the biscuit with dehydrated fruit were expected to be more liked when they were evoked as images (p<0.001, respectively). No significant differences were found in the expected liking for the apple and the Marie style biscuit when both samples were evoked as food names and images (*p*>0.05, respectively).

4.2.2.2. Emotion profiles

The emotional response elicited by the six food samples, evoked as food names or images, was measured with food-specific emoji. The results obtained in this study are shown in Table 9.

All emoji could individually discriminate among the samples evoked as food names (*p*<0.05), but they could not provide different emotion profiles when the samples were evaluated as images (*p*>0.05). When samples were evaluated as food images, all products evoked a positive emotional response characterised by a frequent selection of the positively valenced emoji. Consequently, no significant differences were found on the emotion profiles elicited by the samples evoked as images.

On the contrary, different emotional responses were measured when the samples were evoked as food names. The biscuit with chocolate chips and the cupcake, two of the most liked samples of the study, were associated with positively valenced emoji. Significantly higher frequencies of use of the s*miling face with heart-shaped eyes* (😍) emoji were obtained for these two samples compared with the other food names elicited in the study. Additionally, strong associations (frequencies equal or over 50% of participants) were also established between the *grinning face with smiling eyes (*😁*)* and the *face savouring delicious food* (😋) emoji with the biscuit with chocolate chips.

Table 9. Emotional response elicited by the six food samples evaluated in the study evoked as food names and images. Results are shown as the percentage of participants that selected an emoji for each sample. Averages for positive, neutral, and negative emoji are also displayed. Significant associations between the emoji and the samples (frequency of use of the emoji ≥20% of participants) appear in bold. Liking mean scores are also displayed at the bottom for a better understanding of the results.

	Food names							Images						
Emoji	Biscuit with dehydrated fruit (%)	Cornflakes (%)	Marie style biscuit (%)	Apple (%)	Cupcake (%)	Biscuit with chocolate chips (%)	p-value	Biscuit with dehydrated fruit (%)	Cornflakes (%)	Marie style biscuit (%)	Apple (%)	Cupcake (%)	Biscuit with chocolate chips (%)	p-value
Positive														
😍	5 ^{b}	17 ^{b}	16 ^{b}	18 ^{b}	**35** ^{a}	**45** ^{a}	***	**31** ^{a}	**27** ^{a}	**24** ^{a}	**27** ^{a}	**24** ^{a}	**27** ^{a}	n.s.
😊	11 ^{c}	**26** ^{bc}	**39** ^{ab}	**42** ^{ab}	**45** ^{a}	**42** ^{ab}	***	**43** ^{a}	**34** ^{a}	**27** ^{a}	**35** ^{a}	**31** ^{a}	**27** ^{a}	n.s.
😁	8 ^{d}	**22** ^{cd}	**22** ^{cd}	**31** ^{bc}	**41** ^{ab}	**50** ^{a}	***	**37** ^{a}	**35** ^{a}	**29** ^{a}	**28** ^{a}	**28** ^{a}	**28** ^{a}	n.s.
😜	6 ^{b}	19 ^{ab}	**20** ^{ab}	14 ^{ab}	**28** ^{a}	**28** ^{a}	***	**20** ^{a}	17 ^{a}	18 ^{a}	19 ^{a}	**24** ^{a}	**24** ^{a}	n.s.
😋	7 ^{c}	**33** ^{b}	**37** ^{b}	**36** ^{b}	**44** ^{ab}	**58** ^{a}	***	**36** ^{a}	**37** ^{a}	**38** ^{a}	**36** ^{a}	**37** ^{a}	**37** ^{a}	n.s.
😛	9 ^{c}	14 ^{c}	**20** ^{bc}	**20** ^{bc}	**33** ^{ab}	**41** ^{a}	***	**26** ^{a}	**23** ^{a}	**21** ^{a}	**21** ^{a}	**25** ^{a}	**24** ^{a}	n.s.
Neutral														
😐	**29** ^{a}	18 ^{ab}	**25** ^{a}	**20** ^{ab}	12 ^{ab}	7 ^{b}	***	14 ^{a}	17 ^{a}	18 ^{a}	18 ^{a}	17 ^{a}	19 ^{a}	n.s.
🙄	18 ^{a}	11 ^{ab}	10 ^{ab}	10 ^{ab}	7 ^{ab}	4 ^{b}	*	9 ^{a}	16 ^{a}	8 ^{a}	11 ^{a}	8 ^{a}	9 ^{a}	n.s.
😑	18 ^{a}	13 ^{ab}	8 ^{ab}	8 ^{ab}	6 ^{ab}	2 ^{b}	**	12 ^{a}	8 ^{a}	11 ^{a}	13 ^{a}	13 ^{a}	11 ^{a}	n.s.
Negative														
😖	**30** ^{a}	11 ^{b}	5 ^{b}	3 ^{b}	3 ^{b}	0 ^{b}	***	12 ^{a}	6 ^{a}	4 ^{a}	5 ^{a}	9 ^{a}	8 ^{a}	n.s.
😠	11 ^{a}	5 ^{ab}	2 ^{b}	0 ^{b}	3 ^{b}	2 ^{b}	***	3 ^{a}	2 ^{a}	3 ^{a}	1 ^{a}	4 ^{a}	3 ^{a}	n.s.
🤮	**28** ^{a}	13 ^{b}	5 ^{bc}	1 ^{c}	4 ^{bc}	0 ^{c}	***	5 ^{a}	4 ^{a}	7 ^{a}	8 ^{a}	11 ^{a}	8 ^{a}	n.s.
🤢	**30** ^{a}	14 ^{b}	4 ^{bc}	4 ^{bc}	5 ^{bc}	1 ^{c}	***	9 ^{a}	6 ^{a}	11 ^{a}	8 ^{a}	15 ^{a}	11 ^{a}	n.s.
😡	11 ^{a}	4 ^{b}	0 ^{b}	1 ^{b}	1 ^{b}	1 ^{b}	***	2 ^{a}	1 ^{a}	8 ^{a}	5 ^{a}	4 ^{a}	2 ^{a}	n.s.
Positives	8 ^{d}	**22** ^{c}	**26** ^{bc}	**27** ^{ab}	**38** ^{ab}	**44** ^{a}	***	**32** ^{a}	**29** ^{a}	**26** ^{a}	**28** ^{a}	**28** ^{a}	**28** ^{a}	n.s.
Neutral	**22** ^{a}	14 ^{ab}	14 ^{ab}	13 ^{abc}	8 ^{bc}	4 ^{c}	***	12 ^{a}	14 ^{a}	12 ^{a}	14 ^{a}	13 ^{a}	13 ^{a}	n.s.
Negatives	**22** ^{a}	9 ^{b}	3 ^{c}	2 ^{c}	3 ^{c}	1 ^{c}	***	6 ^{a}	4 ^{a}	7 ^{a}	5 ^{a}	9 ^{a}	6 ^{a}	n.s.
Liking	2.8 ^{e}	4.4 ^{d}	4.9 ^{cd}	5.4 ^{bc}	5.7 ^{ab}	6.2 ^{a}	***	5.3 ^{a}	5.4 ^{a}	5.1 ^{a}	5.2 ^{a}	4.9 ^{a}	5.1 ^{a}	n.s.

[(x)] Means in the same row with the same superscript are not significantly different at $p>0.05$ according to Sheskin test. * $p<0.05$, ** $p<0.01$, *** $p<0.001$.

The biscuit with dehydrated fruit, the only sample that was expected to dislike, elicited a negative emotional response on the participants when it was evoked as food name. Associations with frequencies of use equal or over 20% of the participants were established between this sample and neutral/negative emoji as a group, and specifically with the *neutral face* (😐), *confounded face* (😖), *face with open mouth vomiting* (🤮), and *nauseated face* (🤢) emoji. Medium-liked samples such as the Marie style biscuit and the cornflakes obtained lower frequencies of choice of positively valenced emoji compared to the most liked samples, but higher frequencies of neutral emoji. Similarly, the apple, which was also a medium-liked sample, evoked an emotional response characterised by the selection of both positive and neutral emoji.

Correspondence Analysis (CA) were performed to deepen on the discrimination ability of the emoji-based tool. The symmetry plots displayed in Figure 19 explained the 97.80% of data variability when the samples were evoked as food names (Figure 19A) and 77.95% when they were elicited as images (Figure 19B) within the first two axes.

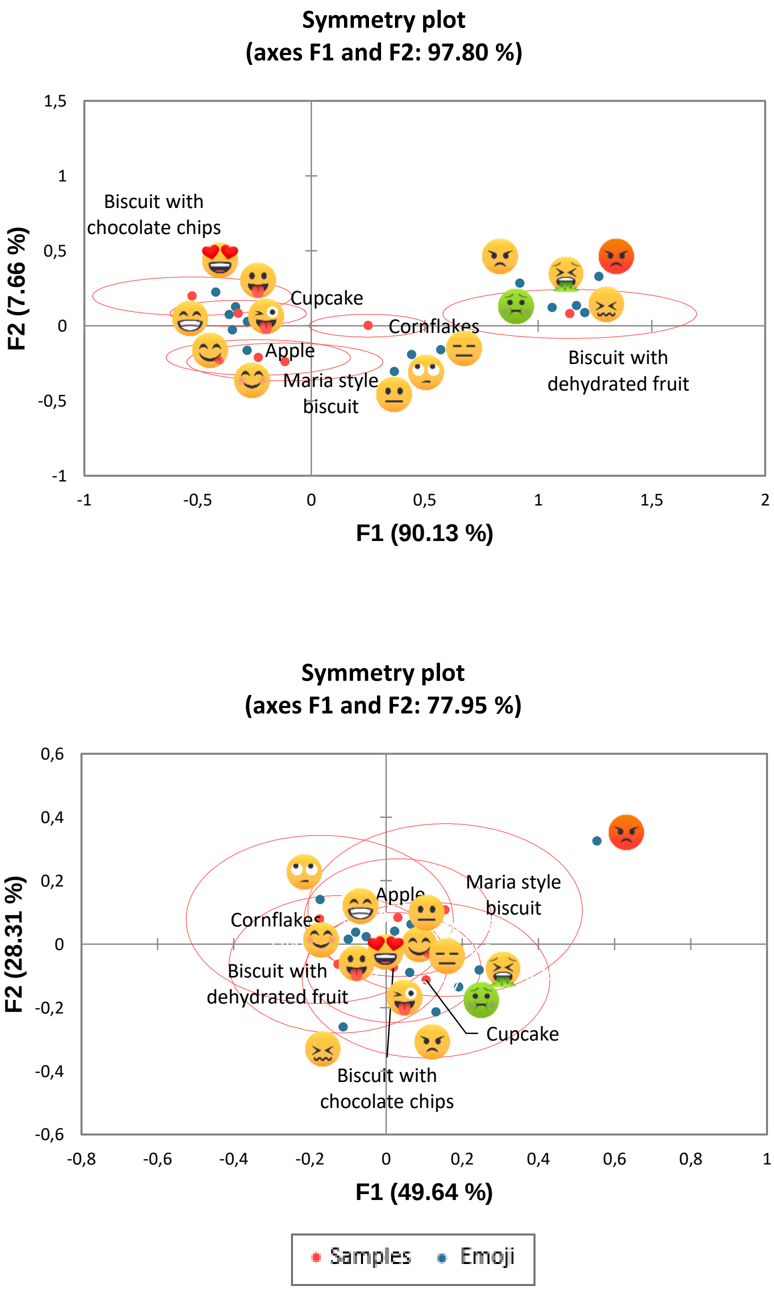


Figure 19. Symmetry plots of the Correspondence Analysis (CA) that represent the samples evaluated and the food-specific emoji. A: samples evoked as food names. B: samples evoked as food images. The 95% confidence ellipses are also displayed for the samples.

Regarding Figure 19A, the first factor might be related to liking or to valence, since liked samples and positively valenced emoji were placed on its left side, as well as disliked samples and negative emoji were located on the right side of the quadrants. Additionally, medium-liked samples and neutrally valence emoji fell in the middle. The second factor seemed to relate to arousal since more arousing emoji were placed on the upper side, while less arousing icons were located on the lower side of the quadrants.

The overlapping of the 95%-ellipses of confidence (Figure 19A) suggested that the evocation of the six food names elicited four emotional responses that could be discriminated with the food-specific emoji. The biscuit with dehydrated fruit and the cornflakes were totally discriminated. In addition, two subgroups of samples with equivalent liking ratings and emotion profiles, were identified: (i) the biscuit with chocolate chips and the cupcake, as well as (ii) the apple and the Marie style biscuit. However, the list of food-specific emoji was indeed able to discriminate the emotion profile evoked by some samples with equivalent liking ratings, e.g., the Marie style biscuit (4.9) and the cornflakes (4.4), as well as the cupcake (5.7) and the apple (5.4). On the contrary, the total overlapping of the 95%-ellipses of confidence in Figure 19B suggested that the food-specific emoji used in the study could not discriminate among the food images evaluated.

4.2.3. *Discussion*

4.2.3.1. Food specificity of emoji

A total of 17 out of the 30 emoji initially evaluated were identified as food-specific for seven varied evoked contexts. The association established between the general food context with a larger number of positively valenced emoji compared to the neutral and negative ones could be related to the hedonic asymmetry phenomenon (Desmet & Schifferstein, 2008) because healthy consumers tend to associate food with a positive emotional response. Even though strong associations were established between specific positive emoji and the situation in which a very liked product was evoked*,* positive emoji were broadly selected to represent the situations in which a food product was liked or very liked. On the contrary, neutral and negative emoji were more specifically chosen to defined other food-related contexts, e.g., the relevance of the emoji that convey anger (*angry face* (😠) and *pouting face* (😡)) only in a situation in which a food product is completely refused and the child deny eating. The applicability of a range of positively valenced emoji on the same contexts pointed out to possible redundancies that were dimensionally and semantically hypothesised in Study 1 of this dissertation (section 4.1.). The possibility of redundancies in emojis with a graphic design based on smiling faces were outlined for adults ((Jaeger & Ares, 2017), but not for school-aged children.

Interestingly, any emoji that mainly portrayed emotions of sadness, surprise or fear was meaningful for the school-aged children in the contexts evaluated. Similarly, no significant associations were found by Sick, Spinelli, et al. (2020) between surprise and scared emoji with a selection of evoked food context in a study with 9-13 yrs pre-adolescents, but sad emoji (i.e., *crying face* (😢) or *loudly crying face* (😭)) were indeed related to the most disliked food.

4.2.3.2. Food-specific emoji usage

Independently of the nature of the stimulus (food names or images), evoked samples with high expected liking elicited a positive emotional response characterised by the selection of positively valenced emoji. A similar trend was observed in other studies in which adults and children evaluated tasted foods and written stimuli (Jaeger, Roigard, et al., 2018; Schouteten et al., 2019). Specifically, it is noteworthy to mention that the *face with heart-shaped eyes* (😍) emoji was more frequently selected to describe the emotion elicited by samples that were expected to be highly liked. Associations with highly liked food products and the evocation of a positive emotional response related to feelings of love were also reported for this emoji by Jaeger & Ares (2017), Schouteten et al. (2019) and in Study 1 of this dissertation (section 4.1.).

On the contrary, the evoked sample that was expected to be disliked, the biscuit with dehydrated fruit, elicited a negative emotional response characterised by a frequent selection of negatively valenced emoji only when it was evoked as food name. The emoji selected were significantly related to the emotion categories "disgust" and "angry" in a food-related context in a previous study (section 4.1.). However, based on the results obtained in section 4.2.1. of this work, we could hypothesise that this sample was expected to be disliked, but not completely refused due to the low frequencies of choice obtained for the emoji related to anger (*angry face* (😠) and *pouting face* (😡)), which were characteristic of this situational context. A similar usage of negatively valenced emoji was obtained by Sick, Spinelli, et al. (2020) in a study in which pre-teenagers reported the feelings evoked by "the most disliked food" with written context.

Neutral emoji obtained higher frequencies of use when the emotion elicited by the food names of slightly liked and disliked samples were evaluated. This usage could be influenced by the children's perception that neutral emoji are neutrally and slightly negatively valenced (Study 1, section 4.1.). Within this group, *neutral face* (😐) was the emoji more frequently used. These results are in line with the findings reported by Schouteten et al. (2019) in a study with children aged 8-11 yrs in which  was frequently selected to described the less liked samples of the products tasted.

Our findings pointed out that the evocation of samples as food names and images elicited a different expected liking and emotional response in children for products that were very liked and disliked. Highly liked products (i.e., biscuit with chocolate chips and cupcake) obtained a higher expected liking when they were evoked as food names rather than as images. An explanation could be associated with the possible idealisation of food names caused by memories (Cardello et al., 2012; King et al., 2013; Meiselman, 2013). On the other hand, food images may be too specific, what may limit their relevance to some participants and hinder their recognition (Jaeger, Roigard, et al., 2018). The results obtained in our study for the elicitation of the biscuit with dehydrated fruit as an image reflect this effect. This sample was expected to be liked and elicited a positive emotional response when it was evoked as an image, unlike when it was evoked as a food name. The difference between both stimuli could rely on the fact that the pieces of dehydrated fruit were not easily recognised in the image, what may difficult the identification of the sample and increased their expected liking. As reported by da Quinta et al. (2021) the presence of fruit as pieces or as a filling reduces the acceptability of biscuits in school-aged children.

4.2.3.3. Discrimination ability of food-specific emoji

According to the Cochran's Q test, the 14 food-specific emoji showed individual discrimination ability for the six samples evoked as food names, but no discrimination was possible for the samples evoked as images. Additionally, the Correspondence Analysis (CA) performed on data obtained in the food name's task showed that only the emotion profiles elicited by the biscuit with dehydrated fruit and the cornflakes could be completely discriminated with the emoji-based tool. These results suggested that the list of food-specific emoji was insufficient to discriminate all the evoked samples. To evaluate the causes that could have influenced this result, two groups of possible reasons were identified.

4.2.3.3.1.Causes related to the emoji-based tool

Within this group, two subgroups of causes that might have influenced the emoji usage were categorised: i) the list of food-specific emoji was too short, and ii) the emoji were not totally relevant for the specific task performed. Regarding the former, the possibility to obtain a low discrimination ability with short lists of emoji due to a reduce variability of items was previously considered by Jaeger et al. (2019). However, despite the methodological differences in comparison to our work, lists of a similar number of graphical items were successfully used in studies with adults and children (Desmet et al., 2000; Deubler et al., 2019; Swaney-Stueve et al., 2018). Indeed, Schouteten et al. (2019) reported that young schoolchildren preferred to use lists of no more than 20 items in CATA questions.

Regarding the latter, the low frequencies of use observed for some emoji (e.g., *face with rolling eyes* (🙄), *expressionless face* (😑) and *angry face* (😠)) might suggest a lack of relevancy when expressing the emotion elicited by the evoked samples. The low frequency of use of the neutral emoji (🙄 and 😑) might have been influenced by the fact that, according to the results obtained in section 4.2.1., neutral emoji are only applicable to convey the emotions elicited by samples that are neither liked nor disliked. The fact that any evoked sample was considered as neither liked nor disliked by the children might have led to the perception that neutral emoji were unrelated and inapplicable. In the same line, Sick, Spinelli, et al. (2020) reported low frequencies of selection of neutrally valenced emoji for different evoked context due to irrelevancy.

Similarly, the *angry face* (😠) emoji was only applicable in a context in which the food product was very dislike and the child reject to consume it. Consequently, the samples that were expected to dislike in our study may have not elicited such a negative emotional response enough to trigger the rejection behaviour.

4.2.3.3.2.Causes related to the evoked samples

The literature published on this topic suggests that the product category and the liking perception of the samples have a key role in the emoji performance.

4.2.3.3.2.1.Expected liking

The list of food-specific emoji used was able to discriminate among samples with different expected liking ratings. On the contrary, our results suggested that the emoji-based tool showed limited discrimination ability among samples with equivalent liking ratings since the pairs of samples composed of the biscuits with chocolate chips and the cupcake as well as the Marie style biscuit and the apple could not be discriminated. Jaeger, Lee, et al. (2017) outlined that the evaluation of samples in a broad span of liking scores made the emoji more discriminant than the study of samples from a narrower liking span. On this regard and to explain the limited applicability obtained in our study, we hypothesise that the limitation showed by our list of food-specific emoji might be related to the arousal perception of the samples. As Figure 19A shows, samples with equivalent expected liking and no overlapping of the 95%-ellipses of confidence were located in different positions on the second factor of the plot (related to arousal), one above the other. On the other hand, samples with equivalent liking scores and overlapping of the 95%-ellipses of confidence were placed at the same level on the second factor of the plot. According to this hypothesis, the evocation of a cupcake as a food name would elicit a more arousing response than the apple and, similarly, the cornflakes would evoke a more arousing response than the Marie style biscuit, even though they scored equivalent expected liking.

In future studies, some improvements should be made to ensure that samples with equivalent liking ratings and levels of arousal are discriminated by emoji-based tools in studies with school-aged children. As suggested by Ares & Jaeger (2017), the use of the methodology RATA (Rate-All-That-Apply) instead of CATA could improve the emoji performance.

4.2.3.3.2.2.Product category

Three of the samples evoked in this study belonged to the same product category (i.e., biscuits) while the other samples represented different product categories. The Correspondence Analysis conducted showed that the three biscuits have different emotion profiles that could be discriminated with the food-specific emoji. On the other hand, and contrary to the results obtained by other authors with school-aged children (Schouteten et al., 2018; Swaney-Stueve et al., 2018), some samples from different product categories could not be totally discriminated with the emoji-based tool. Considering that it should be easier to differ the emotion profiles evoked by samples from different product category rather than from the same category, as Swaney-Stueve et al. (2018) highlighted, the results obtained may suggest that children gave more importance to the expected liking and to the arousal response rather than to the product category when reporting their emotions.

4.3. Study 3. Applicability of food-specific emoji in studies with real food samples

4.3.1. Liking

To evaluate the applicability of the emoji-based tool in studies with real food samples, six texture-modified prototypes were designed. The children that participated in the study reported their liking for each sample with a 7-point hedonic scale. Results obtained for the liquid and the solid samples are shown separately in Figure 20.

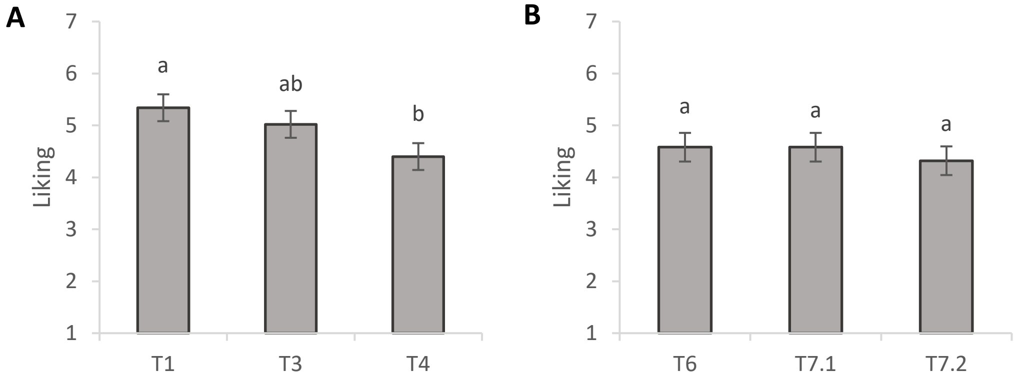


Figure 20. Liking ratings provided by children (N=50) for texture-modified samples designed according to the International Dysphagia Diet Standardisation Initiative (IDDSI, 2019). A: liquid samples for the 1, 3, and 4 texture levels. B: solid samples for the 6, 7-easy to chew (as 7.1) and 7-regular (as 7.2) texture levels. Data is shown as mean and 95%-interval of confidence. The same letters do not differ significantly ($p > 0.05$) according to the Tukey's test.

Significant differences were obtained on the liking ratings of the liquid samples (Figure 20A). The T1 prototype, the thinnest liquid evaluated, was significantly more liked than the T4 sample which was the thickest product tested from the group of liquid samples. Contrary, the solid samples evaluated in the study were equivalently liked by the children (Figure 20B).

4.3.2. Emotional response

The emotional response evoked by the food samples was evaluated with the emoji-based tool developed in the Study 2 of this dissertation (section 4.2.).

For an easier exposure, results obtained for liquid and solid samples are presented separately.

4.3.2.1. Liquids

The emotional response evoked by the liquid food samples tested in this study is shown in Table 10.

Table 10. Selection of food-specific emoji conducted by children (N=50) to describe the emotional response elicited by three liquid samples designed according to the International Dysphagia Diet Standardisation Initiative (IDDSI, 2019). Samples corresponded to the 1, 3, and 4 texture levels of IDDSI. Emoji are listed according to the mean scores for valence in a food-related context obtained in the Study 1 of this dissertation (section 4.1.). Results are displayed as the frequency of selection of each emoji for each sample in the RATA-as-CATA question, but as the mean score for the intensity of the emotion portrayed by the emoji in a 0 to 3 scale for the mean RATA question. Averages for positive, neutral, and negative emoji are also displayed. Liking mean scores are also shown at the bottom for a better understanding of the results.

	RATA-as-CATA				Mean-RATA			
Emoji	**T1**	**T3**	**T4**	***p*-value**	**T1**	**T3**	**T4**	***p*-value**
Positive								
	26^{a}	26^{a}	26^{a}	n.s.	0.58^{a}	0.73^{a}	0.67^{a}	n.s.
	30^{ab}	45^{a}	23^{b}	*	0.74^{a}	1.21^{a}	0.68^{a}	n.s.
	32^{a}	32^{a}	23^{a}	n.s.	0.92^{a}	0.92^{a}	0.64^{a}	n.s.
	26^{a}	23^{a}	32^{a}	n.s.	0.56^{a}	0.72^{a}	0.90^{a}	n.s.
	45^{a}	23^{ab}	38^{b}	*	1.18^{a}	0.58^{a}	0.87^{a}	n.s.
	30^{a}	30^{a}	28^{a}	n.s.	0.72^{a}	0.83^{a}	0.74^{a}	n.s.
Neutral								
	21^{a}	23^{a}	32^{a}	n.s.	0.51^{a}	0.55^{a}	0.66^{a}	n.s.
	21^{a}	26^{a}	23^{a}	n.s.	0.47^{a}	0.49^{a}	0.47^{a}	n.s.
	9^{a}	6^{a}	19^{a}	n.s.	0.15^{a}	0.13^{a}	0.36^{a}	n.s.
Negative								
	4^{a}	17^{a}	15^{a}	n.s.	0.06^{a}	0.38^{a}	0.30^{a}	n.s.
	0^{b}	0^{b}	7^{a}	*	0.00^{a}	0.00^{a}	0.17^{a}	n.s.
	2^{b}	2^{b}	10^{a}	*	0.06^{a}	0.06^{a}	0.26^{a}	n.s.
	2^{b}	2^{b}	11^{a}	*	0.06^{a}	0.06^{a}	0.28^{a}	n.s.
	0^{a}	0^{a}	2^{a}	n.s.	0.00^{a}	0.00^{a}	0.07^{a}	n.s.
Positives	32^{a}	30^{a}	28^{a}	n.s.	0.77^{a}	0.81^{a}	0.75^{a}	n.s.
Neutral	17^{b}	18^{ab}	25^{a}	*	0.38^{a}	0.39^{a}	0.50^{a}	n.s.
Negatives	2^{b}	4^{ab}	9^{a}	**	0.04^{b}	0.10^{a}	0.21^{a}	***
Liking	5.3^{a}	5.0^{ab}	4.4^{b}	*	5.3^{a}	5.0^{ab}	4.4^{b}	*

Means in the same row with the same superscript are not significantly different at $p>0.05$ according to Sheskin test in RATA-as-CATA analysis and to Tukey's test in mean RATA questions and liking. * $p<0.05$, ** $p<0.01$, *** $p<0.001$, n.s. not significant.

The three liquid samples evaluated in this study evoked different emotional responses measured with food-specific emoji (Table 10). When results were analysed as RATA-as-CATA, 5 out of the 14 emoji individually discriminated among samples. The positively valenced emoji (*face savouring delicious food* () and *smiling face with smiling eyes* ()) were more frequently selected to describe the emotion conveyed by T1 and T3 samples compared to T4. Contrary, three negatively valenced emoji (*angry face* (), *face with open *mouth vomiting* (🤮), and *nauseated face* (🤢)) were significantly associated with the thicker product, T4. Additionally, neutral and negative emoji were on average more frequently selected to describe the emotions elicited by the T4 sample.

When food-specific emoji were rated as mean RATA, none of the emoji were individually discriminative among samples. However, negatively valenced emoji showed discrimination ability on average, being more frequently selected to describe the emotions elicited by T3 and T4 compared to T1.

Additionally, to deepen into sample discrimination and sample configurations, multivariate analysis was carried out on RATA-as-CATA and mean RATA data. The results obtained for the Correspondence Analysis (CA) conducted on RATA-as-CATA data is shown in Figure 21A, whereas the results obtained for the Principal Component Analysis (PCA) performed on mean RATA data is presented in Figure 21B.

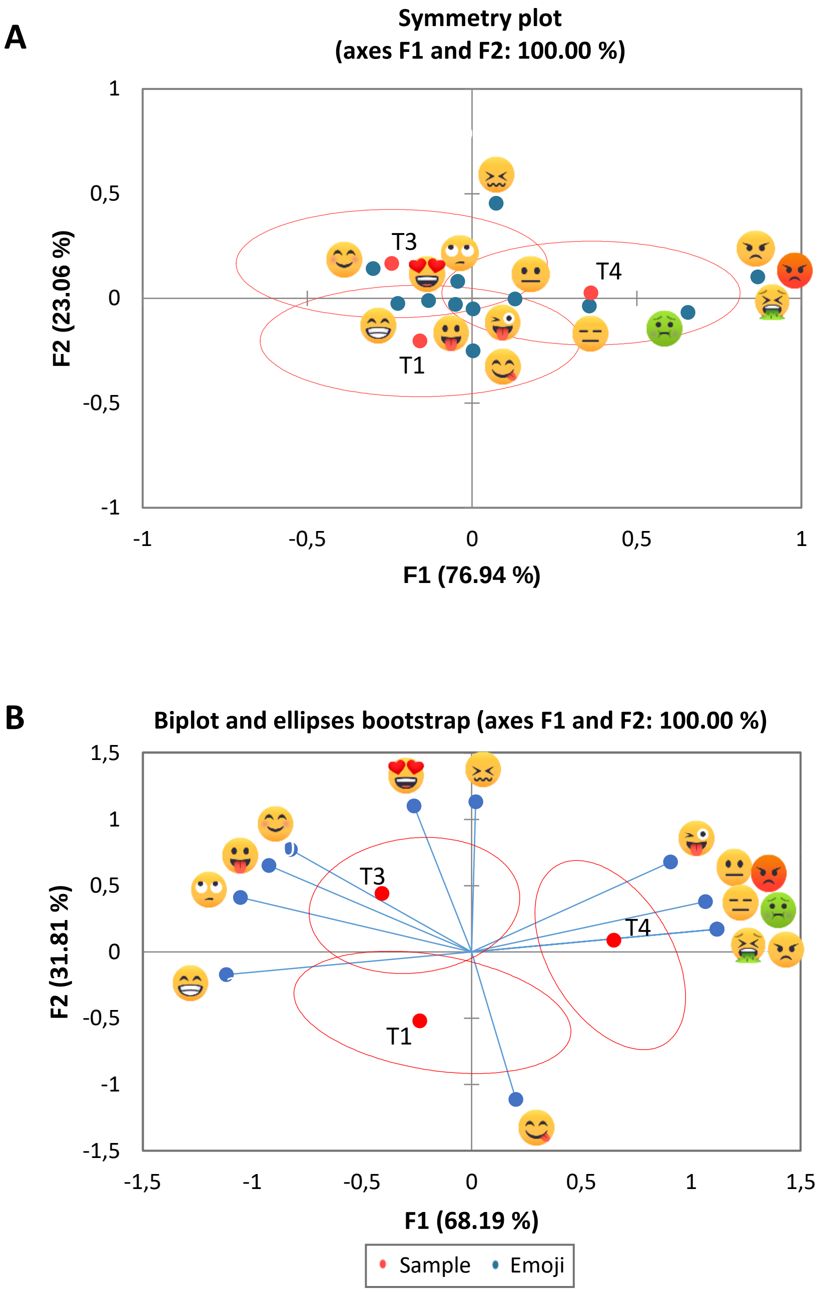


Figure 21. Multivariate analysis performed on the three liquid samples and the food-specific emoji. Samples corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). A: symmetry plot of the Correspondence Analysis (CA) performed on the results obtained in the RATA-as-CATA analysis. B: overlapping of the biplot and ellipses bootstrap plots of the Principal

Component Analysis (PCA) carried out on the mean RATA data. The 95% confidence ellipses are also displayed for the samples.

The overlapping of the 95%-ellipses of confidence shown in Figure 21A suggested that the three liquid samples tested in this study elicited an equivalent emotional response. This response could not be discriminated with the food-specific emoji when results were analysed in a RATA-as-CATA layout. On the other hand, Figure 21B showed that the analysis of mean RATA data with 3 levels of intensity discriminated the T4 sample from T1 and T3. The T4 sample, the thickest from the liquid products evaluated, was mostly associated with negative (*face with open mouth vomiting* (🤮), *angry face* (😠), *pouting face* (😡), and *nauseated face* (🤢)), and neutral emoji (*neutral face* (😐) and *expressionless face* (😑)), but also with the positive emoji *face with stuck-out tongue and winking eye* (😜). Contrary, the T1 and T3 samples were associated with most positively valenced emoji, but also with *confounded face* (😖) and *face with rolling eyes* (🙄) emoji (negative and neutral, respectively).

4.3.2.2. Solids

The emotional response evoked by the solid samples tested in this study is shown in Table 11.

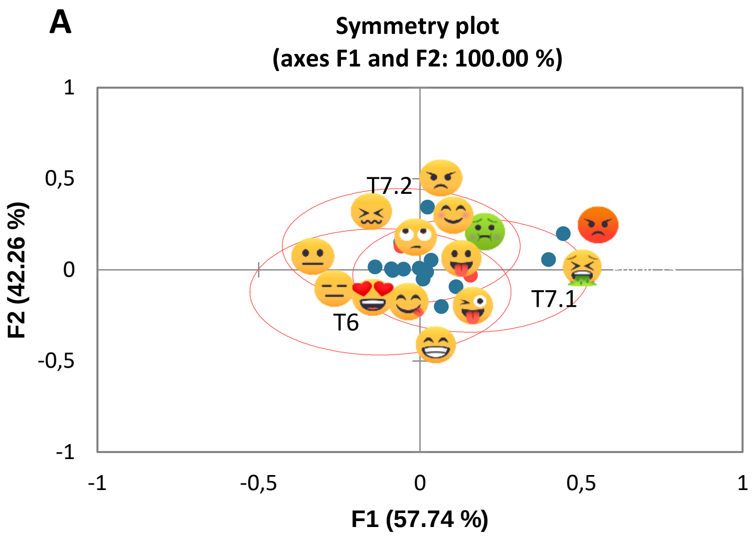
Table 11. Selection of food-specific emoji conducted by children (N=50) to describe the emotional response elicited by three solid samples designed according to the International Dysphagia Diet Standardisation Initiative (IDDSI, 2019). Samples corresponded to the 6, 7-easy to chew (as 7.1) and 7-regular (as 7.2) texture levels of IDDSI. Emoji are listed according to the mean scores for valence in a food-related context obtained in the Study 1 of this dissertation (section 4.1.). Results are displayed as the frequency of selection of each emoji for each sample in the RATA-as-CATA question, but as the mean score for the intensity of the emotion portrayed by the emoji in a 0 to 3 scale for the mean RATA question. Averages for positive, neutral, and negative emoji are also displayed. Liking mean scores are also shown at the bottom for a better understanding of the results.

	RATA-as-CATA				Mean-RATA			
Emoji	**T6**	**T7.1**	**T7.2**	***p*-value**	**T6**	**T7.1**	**T7.2**	***p*-value**
<u>Positive</u>								
😍	21 [a]	21 [a]	26 [a]	n.s.	0.60 [a]	0.60 [a]	0.76 [a]	n.s.
😊	28 [a]	30 [a]	30 [a]	n.s.	0.70 [a]	0.80 [a]	0.82 [a]	n.s.
😁	32 [a]	34 [a]	21 [a]	n.s.	0.72 [a]	1.02 [a]	0.54 [a]	n.s.
😜	15 [a]	23 [a]	17 [a]	n.s.	0.50 [a]	0.72 [a]	0.48 [a]	n.s.
😋	32 [a]	36 [a]	28 [a]	n.s.	0.78 [a]	0.92 [a]	0.82 [a]	n.s.
😛	21 [a]	26 [a]	26 [a]	n.s.	0.62 [a]	0.72 [a]	0.70 [a]	n.s.
<u>Neutral</u>								
😐	32 [a]	28 [a]	40 [a]	n.s.	0.78 [a]	0.72 [a]	0.90 [a]	n.s.
🙄	28 [a]	26 [a]	30 [a]	n.s.	0.68 [a]	0.44 [a]	0.74 [a]	n.s.
😑	21 [a]	19 [a]	26 [a]	n.s.	0.48 [a]	0.50 [a]	0.64 [a]	n.s.
<u>Negative</u>								
😖	17 [a]	19 [a]	28 [a]	n.s.	0.36 [a]	0.46 [a]	0.70 [a]	n.s.
😠	2 [b]	4 [ab]	11 [a]	*	0.12 [a]	0.16 [a]	0.22 [a]	n.s.
🤮	4 [a]	13 [a]	9 [a]	n.s.	0.12 [a]	0.32 [a]	0.18 [a]	n.s.
🤢	11 [a]	13 [a]	13 [a]	n.s.	0.18 [a]	0.30 [a]	0.32 [a]	n.s.
😡	0 [a]	9 [a]	9 [a]	n.s.	0.06 [a]	0.22 [a]	0.14 [a]	n.s.
Positives	25 [a]	28 [a]	25 [a]	n.s.	0.65 [a]	0.80 [a]	0.69 [a]	n.s.
Neutral	27 [a]	24 [a]	32 [a]	n.s.	0.65 [a]	0.55 [a]	0.76 [a]	n.s.
Negatives	7 [a]	12 [a]	14 [a]	n.s.	0.17 [b]	0.29 [a]	0.31 [a]	***
Liking	4.6 [a]	4.6 [a]	4.3 [a]	n.s.	4.6 [a]	4.6 [a]	4.3 [a]	n.s.

Means in the same row with the same superscript are not significantly different at $p>0.05$ according to Sheskin test in RATA-as-CATA analysis and to Tukey's test in mean RATA questions and liking. * $p<0.05$, *** $p<0.001$, n.s. not significant.

Small significant differences were obtained on the emotional response evoked by the three solid samples (Table 11). Results from the RATA-as-CATA analysis showed that only the *angry face* (😠) emoji had individual discrimination ability among samples. This emoji was more frequently selected for T7.2, the hardest sample of the study, compared to T6, the softest sample of the solid products tested. Similarly, when the emotion was evaluated as a mean RATA, negatively valenced emoji discriminated among the three samples on average, showing a higher intensity for T7.1 and T7.2 compared to T6.

Similar to the liquid samples, a multivariate analysis was performed on RATA-as-CATA and mean RATA data to evaluate sample discrimination and sample configuration. The results obtained for the CA carried out on RATA-as-CATA data is shown in Figure 22A, whereas the results obtained for the PCA performed on mean RATA data is presented in Figure 22B.



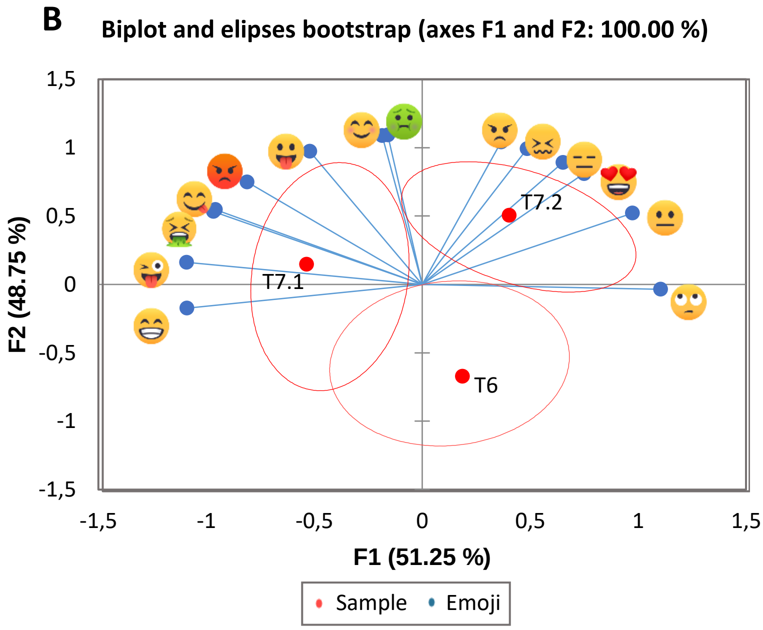


Figure 22. Multivariate analysis performed on the three solid samples and the food-specific emoji. Samples corresponded to the 6, 7-easy to chew (as 7.1) and 7-regular (as 7.2) texture levels of IDDSI (IDDSI, 2019). A: symmetry plot of the Correspondence Analysis (CA) performed on the results obtained in the RATA-as-CATA analysis. B: overlapping of the biplot and ellipses bootstrap plots of the Principal Component Analysis (PCA) carried out on the mean RATA data. The 95% confidence ellipses are also displayed for the samples.

The overlapping of the 95%-ellipses of confidence shown in Figure 22A suggested that the emotional response reported by the children after being exposed to three solid samples was equivalent. The emoji-based tool showed no discrimination for the solid samples when RATA-as-CATA results were considered. Contrary, the food-specific emoji used in this study were discriminative for the three solid samples when data was analysed as mean RATA (Figure 22B). The T7.2 sample, the hardest of the products evaluated in this study, evoked a significantly different emotional response compared to T6 and T7.1. The 7.2 sample was mostly associated with neutral emoji, but also with negatively (*angry face* (😠), *confounded face* (😖) and *nauseated face* (🤢)) and positively (*smiling face with heart-shaped eyes* (😍) and *smiling face with smiling eyes* (😊)) valenced emoji. Additionally, the T6 and T7.1 samples were related to most positively valenced emoji, but also with the negative emoji *pouting face* (😡), and *face with open mouth vomiting* (🤮).

4.3.3. Discussion

4.3.3.1. Liking and emotional response elicited by food textures

All food prototypes were liked or neutrally liked by the children. Small differences in liking and emotional response among food samples were found. This was not surprising since the samples tested in this study were sensorially similar, only varying in texture. Our results suggested that the slightly thick liquid was more appreciated by the children and elicited a more positive emotional response than the extremely thick liquid, which was more related to neutral and negative emotion. These results were not unexpected since previous studies reported that schoolchildren prefer simple rather than complex food textures. Young children up to four yrs reduced their acceptability and consumption of yoghurts when the texture became lumpy and difficult to manipulate in the mouth (Werthmann et al., 2015). Similarly, Laureati et al. (2017) concluded that a smooth and uniform texture were positive predictors of apple purees liking for children aged 8-11 yrs. The explanation to this behaviour relies on primitive reasons. Children like to be in control of the food that is present in their mouths and to avoid heterogeneous textures to prevent choking (Szczesniak, 2002).

Our findings on the emotional response elicited by liquid textures in children could not be compared to previous studies because, to the authors knowledge, there are no published papers that researched on this topic. However, associations between positively valenced emoji with the most liked samples were reported by other authors that researched on topics beyond texture. Similar emoji uses were reported by Schouteten et al. (2019) for 8-11 yrs children in tasting experiences with different types of speculoos and in the Study 2 of this dissertation (section 4.2.) for 6-12 yrs children when a variety of samples were evoked as food names.

Unexpectedly, our findings showed that school-aged children equivalently liked solid food products designed to have soft and hard textures. Contrary, these food products were indeed able to evoke a slightly different emotional response, being the hardest sample more associated with a negative emotion compared to the softest product. These findings were opposed to da Quinta et al. (2021) and Sandvik et al. (2021) who reported that Spanish children aged 6-12 yrs preferred soft rather than hard textures for solid food products (different types of biscuits). An explanation to this result might be related to an excessive similarity among samples, what could have hindered the recognition of texture differences among prototypes. All samples tested in this study were designed according to the IDDSI Framework (IDDSI, 2019). Nevertheless, it is noteworthy to mention that the guidance to evaluate food products according to this standard is quite open. For example, a liquid is considered as a slightly thick liquid (level 1 of texture) when after dropping of a 10 cm-syringe for 10 seconds, some liquid remains in the syringe for 1-4 cm length (IDDSI, 2019). This range of possibilities led to a span of different textures that matched IDDSI requirements but may increase (or decrease) the differences between successive levels of the scale. According to this theory, the liquid products evaluated in our study could have been perceived as more different from each other (even at the appearance level; see images in section 3.2.2.3.) than the solids. Therefore, the texture differences among solid samples might have been unnoticed for the children what could have led to an equivalent liking perception.

Similar to the liquid products, our findings on the emotional response elicited by solid textures in children could not be compared to previous studies because scientific research on this topic is lacking. However, beyond the food texture context, our results agreed with Study 2 (section 4.2.) and Schouteten et al. (2018, 2019), who associated the negatively valenced emoji with the least liked samples of their studies developed with school-aged children.

4.3.3.2. Mean RATA vs. RATA-as-CATA

A greater number of emoji were discriminative in our study when results were analysed as RATA-as-CATA compared to mean RATA. This result is opposed to the findings reported by Meyners et al. (2016) and Vidal et al. (2018), who obtained a higher percentage of discriminative sensory terms in studies with adults when mean RATA analysis was compared to RATA-as-CATA. Contrary, Ares et al. (2014) reported no significant differences on mean RATA and RATA-as-CATA performance for commercial samples and laboratory prototypes with adults. Regarding our study, a greater individual discrimination ability obtained for RATA-as-CATA compared to mean RATA analysis might pointed out that children could have experienced difficulties in rating the intensity of the emotion felt during the session, even though a training was performed at the beginning of the experiment. Laureati et al. (2015) confirmed that children as young as four years old can correctly use a 3-point scale, like the one used in our study to rate the intensity of the emotion. However, despite having the ability to use the scale, children seemed to do not fully understand the concept of the intensity of an emotion, as it was hypothesised in a prior study (Study 1, section 4.1.4.1.) conducted with children from 6 to 12 yrs.

On the contrary, the multivariate analysis performed in our study showed that only mean RATA analysis discriminated among liquid and solid prototypes. Similarly, Meyners et al. (2016) concluded that mean RATA analysis was slightly more powerful than RATA-as-CATA on the discrimination of sample in studies with adults. However, even though discrimination of samples was obtained in our study with children when data was analysed as mean RATA, Figure XXXB provided no clear emotion profile for each sample, since food products were associated with emoji that belonged to all valence categories. These inconclusive configurations may have been influenced by: (i) the possible misunderstanding of the concept of the intensity of the emotion felt during the evaluation of the samples, or (ii) the possible presence of cluster of consumers that experienced different emotional responses among the group of children. Regarding the former, the allocation of intensities of the emotion for each emoji without complete awareness could have led to misclassification during the analysis. Regarding the latter, the possible presence of clusters of children with different emotional responses could increase the dispersion of data. As Varela (2013) outlined for liking, the calculation of average scores in groups of consumers with segmented behaviours “dilutes” the results and hinders the extraction of conclusions. This theory could explain why only small differences were obtained in the emotional response elicited by the samples when all the children were considered as a group. However, this hypothesis could not be confirmed in this study because a hierarchical cluster analysis could not be conducted due to the reduced number of participants involved in the study. In general, approximately 50 consumers are needed per cluster group to consider the analysis statistically significant (Varela, 2013).

4.4. Study 4. FaceReader's recognition ability for spontaneous facial expressions in the food domain

4.4.1. Recognition ability of action units (AUs)

FaceReader's ability to recognise the AUs defined in FACS (Ekman et al., 2002b) was tested in a first task. The performance metrics obtained for each AU and the average are shown in Table 12.

Table 12. FaceReader 8.0 performance during the codification of AUs in the 27 recordings of the Denver Intensity of Spontaneous Facial Action (DISFA) database (Mavadati et al., 2013). Each recording included 4845 frames, with a total of 130815 frames.

	Description	Present	Precision	Recall	F1	Accuracy
AU01	Inner brow raise	8815	0.31	0.57	0.40	0.88
AU02	Outer brow raise	7373	0.39	0.45	0.42	0.89
AU04	Brow Lowerer	24883	0.58	0.50	0.54	0.76
AU05	Upper lid raise	2764	0.24	0.32	0.27	0.95
AU06	Cheek raise	19651	0.71	0.48	0.57	0.78
AU09	Nose wrinkle	7132	0.21	0.66	0.32	0.90
AU12	Lip corner puller	31533	0.92	0.51	0.66	0.70
AU15	Lip corner depresor	8094	0.07	0.59	0.13	0.93
AU17	Chin raiser	13070	0.35	0.45	0.39	0.80
AU20	Lip stretch	5237	0.05	0.32	0.09	0.94
AU25	Lips part	47237	0.55	0.96	0.70	0.84
AU26	Jaw drop	25841	0.19	0.87	0.31	0.85
Average		-	0.38	0.56	0.40	0.85

The accuracy obtained was high, with values over 0.70 for all the AUs evaluated and 0.85 on average. According to FACS requirements for the quality of recognition (Ekman et al., 2002a) these results suggested that FaceReader 8.0 performed a good codification of AUs when activated and absent AUs were considered, since values equal or over 0.70were obtained in all cases.

As described by Lewinski et al. (2014), F1, the trade-off between precision and recall (see section 3.3.1.4. for a complete description about the metrics) is a suitable measure to evaluate the quality of the software on the individual classification of the AUs. According to FACS requirements (Ekman et al., 2002a), only AU25 obtained good codification with an F1 value over 0.70, but the recognition of AU12 was also acceptable with a F1 value over 0.60. Results displayed in Table 12 suggested that FaceReader 8.0 performed poorly on average, but specifically for AU01, AU02, AU05, AU09, AU15, AU17, AU20, and AU26.

4.4.2. Recognition of the emotional response elicited by evocative images.

FaceReader's ability to identify the emotional valence elicited by standardised images was measured in a group of 36 children. The accuracy of FaceReader on valence categorisation compared to the reference data is shown in Table 13.

Table 13. FaceReader 8.0 performance for the codification of emotional valence in children (N=36) during the observation of 66 images of the OASIS and FRIDa databases (Foroni et al., 2013; Kurdi et al., 2017).

		Present	Precision	Recall	F1	Accuracy
OASIS	**Positive**	900	0.20	0.46	0.28	0.46
	Negative	828	0.74	0.46	0.57	0.46
	Average	-	0.47	0.46	0.42	0.46
FRIDa	**Positive**	432	0.19	0.61	0.29	0.38
	Negative	216	0.76	0.32	0.45	0.38
	Average	-	0.48	0.47	0.37	0.38

FaceReader 8.0 showed poor recognition ability (<0.60) for the emotional valence elicited by OASIS and FRIDa images and displayed by school-aged children. Higher matching scores as F1 were obtained for the images that elicited a negative emotional response compared to positive images in both

databases (i.e., 0.57 vs. 0.28 in OASIS, and 0.45 vs. 0.29 in FRIDa). Indeed, values over 0.70 were obtained in precision for negative images in both databases, what suggested that FaceReader 8.0 performed a few negative errors when coding the emotional response evoked by negative images (i.e., the software missed a short number of negative emotional responses).

4.4.3. Recognition of the emotional response elicited by real food products

This study was performed to evaluate FaceReader's ability to recognise the expressions elicited by pleasant and unpleasant real food samples in a naturalistic environment instead of food images. Liking was measured as an hedonic response that represented the pleasantness induced by the samples.

4.4.3.1. Liking

Significant differences were obtained in liking ratings between the two food products tested in this study (p<0.05; Figure 23). The liquid sample evaluated in this study was liked with an average liking score of 5.3. On the other hand, the solid sample tested was neither liked nor disliked with an average liking rating of 4.3.

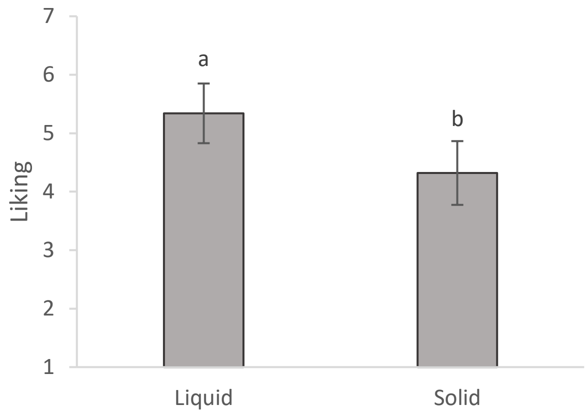


Figure 23. Liking ratings provided by school-aged children (N=45) for a liquid and a solid food sample. Results are displayed as mean and 95%-interval of confidence. Different letters correspond to significant differences in the Student's t test at p=0.05.

4.4.3.2. Emotional response elicited by real food products

Considering that our hypothesis was not correct and that the solid sample was perceived as neither liked nor disliked by the children intead of disliked (or unpleasant), an additional statistical analysis was performed on the emotion data to graphically visualise the associations established between the emotions, liking and the samples (Figure 24).

The emotion profile elicited by both samples was completely different. All the emotional measures taken during the observation of the liquid sample (coded as "L" in the biplot) were located in the right quadrants, while the measures obtained for the solid sample were placed on the left quadrants. The location of liking in the biplot confirmed that the liquid sample was associated with acceptance (or pleasantness), but not the solid sample.

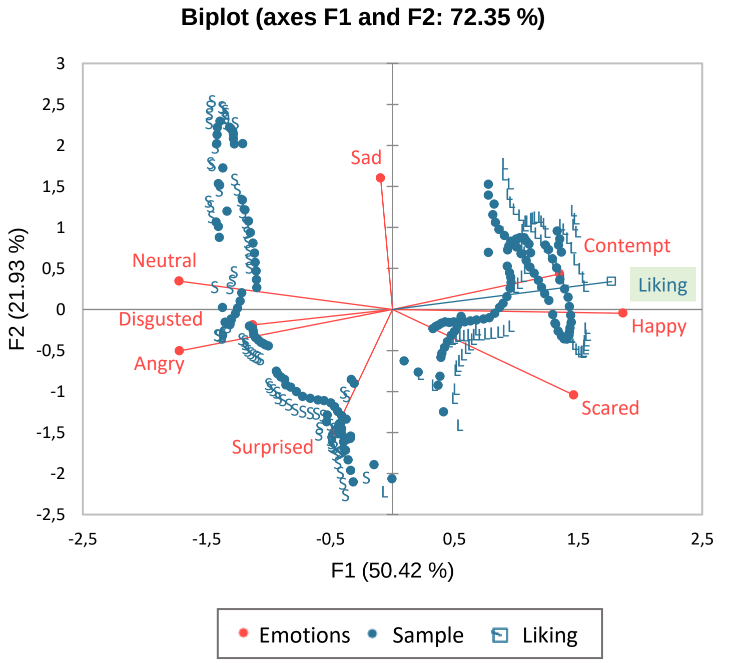


Figure 24. Biplot of the PCA performed on the raw emotion data and the two samples tested in the study. L: liquid sample. S: solid sample. Liking was also displayed as supplementary variable.

Considering the location of liking in the biplot and the discrimination obtained between both samples, we decided to consider the solid product evaluated in this study as unpleasant and the liquid sample as pleasant to determine FaceReader's accuracy for the spontaneous expressions elicited by real food samples. Table 14 shows the performance metrics obtained for FaceReader 8.0 during the experiment.

Table 14. FaceReader 8.0 performance for the codification of emotional valence in children (N=45) during the observation of two food products with different perception of pleasantness.

	Present	Precision	Recall	F1	Accuracy
Pleasant	45	0,31	0,58	0,41	0,54
Unpleasant	45	0,78	0,53	0,63	0,54
Average	-	0,54	0,56	0,52	0,54

The results obtained suggested that FaceReader 8.0 poorly recognised the spontaneous expressions evoked by real food samples on average (F1 value <0.60). An acceptable recognition rate over 0.60 was achieved for the expressions elicited by the unpleasant food sample, but not for the pleasant product (0.41).

4.4.4. Discussion

The results obtained in all the tests performed in this work to determine FaceReader's recognition ability for spontaneous expression are meaningful only in relation to human performance rates for FACS coding.

4.4.4.1. Recognition ability for action units

According to FACS, an agreement index below 0.70 in a range from 0 to 1 is not acceptable for facial coding (Ekman et al., 2002a). Considering this threshold, our study showed that FaceReader 8.0 performed a poor recognition of the activation of AUs, with an average F1 value of 0.40. A possible explanation for the low recognition rates observed in our study might rely on the evaluation of spontaneous rather than posed expressions. It is thought that facial coding softwares perform generally better for posed expressions rather than for spontaneous ones because the expressions displayed in a natural setting are not prototypical (Krumhuber et al., 2021). Indeed, Namba et al. (2021) recently probed that three different facial coding softwares performed a better analysis of AUs on posed rather than in spontaneous expressions.

Namba et al. (2021) reported in the supplementary material a low average F1 metric (0.20) for the spontaneous expressions measured with FaceReader 7.0

in annotated videos from YouTube. Additionally, and supporting our results, it is important to outline that their average was based on eight AUs, whereas ours included twelve. Our findings suggested that FaceReader 8.0 outperformed version 7.0 on average and on the specific codification of all the AUs measured in Namba et al. (2021) study (i.e., AU01, AU02, AU04, AU06, AU12, and AU25) except for AU15 and AU20. On the other hand, Lewinski et al. (2014) and Skiendziel et al. (2019) reported higher F1 values on average and for each AUs compared to the results obtained in our study, what supported the theory that posed expressions are easier to recognise than spontaneous expressions.

FaceReader version 8.0 performed a good (with agreement index $\geq$ 0.70) or acceptable (with agreement index $\geq$ 0.60) codification for AU25 (*lips part*) and AU12 (*lip corner puller*). These two AUs were the most frequently coded in the recordings from the database, what may point out that both AUs take part of common facial expressions. Indeed, both AUs are important for predicting positive emotions. AU12 is crucial for categorising a smile (Girard et al., 2019) and AU25 is associated with bared teeth smiles (Del Giudice & Colle, 2007). These results suggested that FaceReader 8.0 may have a better ability of coding AUs involved in facial expressions that are frequently performed in everyday life. Skiendziel et al. (2019) also reported that FaceReader 7.0 better recognised the activation of AUs that were more frequently displayed in their recording material. This hypothesis might be support by the low matching scores obtained in our study for AUs barely present in the database (e.g., AU05, AU09, AU15, and AU20, coded in 2-6% of the frames) and the medium accuracy scores obtained for other AUs that were frequently coded (e.g., AU04 and AU06, coded in 15-20% of the frames). Nevertheless, an exception to this tendency was observed in our study for AU26 which was also coded as activated in 20% of the frames, but it was poorly recognised by the software. This result might be explained with the phenomenon of co-occurrence reported by Namba et al. (2021). As suggested by Skiendziel et al. (2019), the codification of AU26 might be confused with AU25 and AU27 what could led to misclassification.

4.4.4.2. Recognition ability for emotional responses elicited by food images

FaceReader 8.0 showed on average a poor recognition ability for the spontaneous expressions elicited by evocative images. A direct comparison could only be done with Höfling et al. (2020) even though both studies have methodological differences. These authors reported that FaceReader 7.0 provided a good agreement between the spontaneous expressions elicited by positive images and the participants' self-reported ratings. Stöckli et al. (2018), also reported higher recognition rates on average for AFFDEX (0.67) and FACET (0.57) softwares during the evaluation of the emotional response evoked by standardised images compared to our results (0.48). However, their average was based on six images, whereas ours included 66 pictures, what increased the probability of errors.

The poor recognition ability showed by FaceReader 8.0 was not unexpected since Krumhuber et al. (2017, 2021) suggested that the spontaneous expressions displayed in a natural setting are emotionally ambiguous, not prototypical, relatively subtle and more difficult to classify by both human and machines compared to posed expressions. This research confirmed that FaceReader performed better for negative rather than for positive emotional responses (F1 metrics of 0.51 vs. 0.29 on average). Our findings were consistent with Stöckli et al. (2018) who also reported higher matching scores for AFFDEX during the codification of negative expressions. The low recognition rate obtained in our study for positive emotional responses might have been influenced by the fact that only happy was considered to classify an expression as positive, whereas anger, sad, fear, and disgust were considered for negative expressions. As Stöckli et al. (2018) highlighted, for simple probability the software had more chances to better categorise negative rather than positive expressions. Another explanation that may support the higher accuracy observed for negative expressions relied on the belief that people are more prone to express facial expressions in response to negative stimuli compared to neutral or positive stimuli (Zeinstra et al., 2009), what may facilitate the recognition of negatively valence expressions. Furthermore, the poor recognition ability obtained in our study may point out to an error in the assumption that there was coherence between the pictures, children's emotions, and their facial expressions. It is important to bear in mind that both databases used in our study (OASIS, Kurdi et al. (2017) and FRIDa, Foroni et al. (2013)) were validated with an adult population and not with children. Considering that the mechanisms behind the emotional regulation are age-dependant (Helion et al., 2019; Zimmermann & Iwanski, 2014), it is logical thinking that the images selected for the study might elicit a different emotional response in children compared to the adults that participated in the databases' validation studies.

Lastly, FaceReader 8.0 performed a slightly higher recognition on the expressions elicited by a varied and general group of images (OASIS) compared to food pictures (FRIDa). The lower recognition rate obtained for the food images of FRIDa might have been influenced by an unbalanced selection of stimuli with more positive than negative pictures (432 vs. 216 recordings). This effect could have reduced the accuracy in FRIDa compared to the balanced selection of items from OASIS.

4.4.4.3. Recognition ability for emotional responses elicited by real food samples

The simple observation of two real food products that only differed in texture evoked different spontaneous expressions in children. As hypothesised based on previous studies (da Quinta et al., 2021; Sandvik et al., 2021), the school-aged children appreciated more the liquid sample. The evaluation of the spontaneous facial expressions displayed during the observation of the product suggested that the solid product evoked a negative emotional response in children characterised by anger, disgust, and sadness, whereas the liquid sample elicited a positive emotional response characterised by happiness as well as fear. The fear perception might have been triggered by initial uncertainty because all subjects firstly evaluated the liquid sample. On this regard, a balanced order of presentation could have reduced this bias.

The consideration of the two samples tested in the study as pleasant or unpleasant allowed us to determine FaceReader's accuracy for spontaneous expressions in a naturalistic environment. Similar to the results obtained from evocative images, FaceReader 8.0 poorly recognised the spontaneous expressions evoked by real food samples according to FACS requirements (Ekman et al., 2002a). The software better recognised the expressions elicited by unpleasant compared to pleasant products. Equivalent precision scores were reported by Dibeklioglu & Gevers (2020) for the recognition of spontaneous expressions elicited by disliked beers using a state-of-the-art facial coding system with an average precision of 0.77. Contrary, the software used by these authors provided higher precision scores for the expressions elicited by liked beers compared to our results obtained with FaceReader 8.0 and pleasant products.

The direct comparison of the results reported throughout this study suggested that FaceReader 8.0 was more accurate during the evaluation of real samples compared to the food images of FRIDa (0.52 vs. 0.37 F1 values on average). A possible explanation for this finding may rely on the belief that real food products can elicit a more intense emotional response compared to food images, what may facilitate the recognition of the expressions. This hypothesis might be based on de Wijk et al. (2012) findings, who suggested that sensory tasks that are perceived as more risky or potentially dangerous induce a more intense emotional response (e.g., the evaluation of real food samples instead of still images in our study). However, this hypothesis is not out of discrepancy since Piqueras-Fiszman & Jaeger (2014) reported that a real tasting experience elicited an equivalent emotional response than food images.

Another possible explanation might be associated with the methodological improvements developed in the last study. In the work conducted with evocative images, FaceReader's performance was compared with the reference data reported by Foroni et al. (2013), procedure that has already been outlined as a source of potential bias. Contrary, in the last study, children provided self-reported ratings of liking as an indication of the pleasantness elicited by the food samples, what made the data more realistic and appropriate. A similar approach was considered by Höfling et al. (2020), who evaluated FaceReader's recognition ability for the emotional valence elicited by evocative images with the participants' self-reported ratings.

4.5. Study 5. Children's physiological and behavioural response during the observation, olfaction, manipulation, and consumption of texture-modified liquids

This section has been divided in two subsections to better report the results obtained when facial expressions were separately coded as AUs and basic emotions independently. This evaluation was conducted independently to compare the emotion profiles obtained with both methodologies.

4.5.1. Codification of AUs

The activation of 20 AUs was measured with FaceReader 8.0 during the observation, olfaction, and manipulation of the liquid samples. Appendix 3 shows the PCA ellipses bootstrap obtained for each individual time-range during each task.

4.5.1.1. Observation

During the observation task (Figure 25), a different profile of AUs activation was elicited by the T4 product compared to the T1 and T3 samples implicit and explicitly (0-500 ms, 1000-2000 ms; $p<0.05$, respectively). The T4 product elicited an unconscious activation of AU01, AU02, AU20 and AU10, but a later and conscious activation of AUs located in the centre of the biplot (e.g., AU04 and AU18). Additionally, T4 sample was associated with greater changes in SCR. The discrimination between the T1 and T3 samples was only possible in consciousness at 2000-3000 ms of exposure. Both samples induced the activation of all the AUs located in the lower quadrants of the biplot (i.e., AU26, AU05, AU25, AU27, and AU12) but T1 also activated the AUs placed on the upper-left quadrant during the last second of exposure (i.e., AU04, AU14, AU43, AU06, and AU07). The location of liking in the biplot suggested that this variable was positively associated with the activation of AU12, AU25, AU27, and AU05.

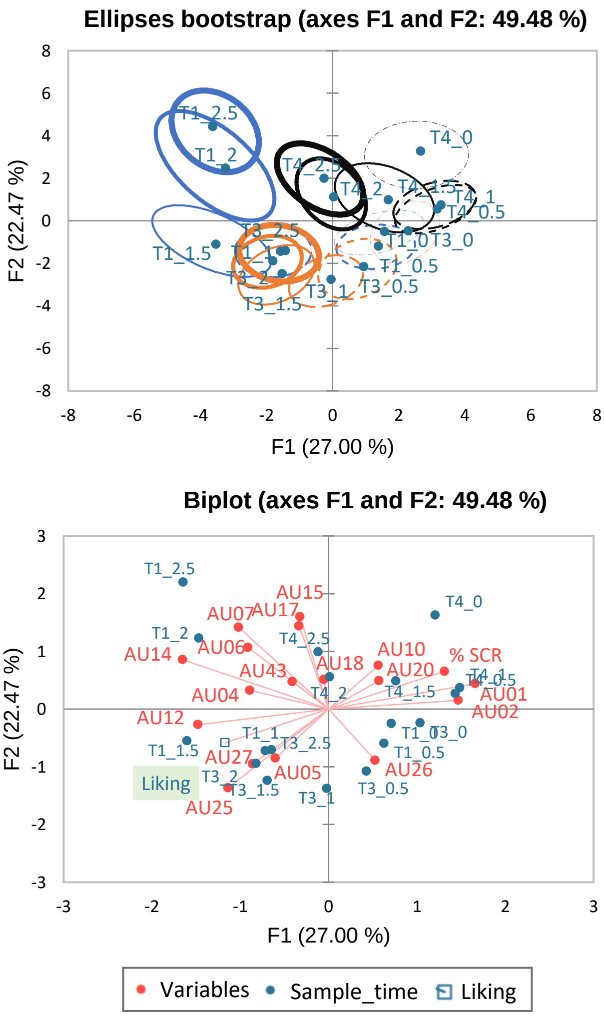


Figure 25. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the observation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.1.2. Olfaction

The overlapping of 95%-ellipses of confidence displayed in the olfaction plot (Figure 26) pointed out that the three liquid samples elicited an equivalent activation of AUs until the 1500 ms of exposure. All samples evoked an unconscious activation of AU43 and AU18. After the first 1500 ms, the T1 sample evoked a different response characterised by the conscious activation of most AUs located in the upper quadrants of the biplot (i.e., AU20, AU07, AU09, AU04, and AU12) compared to the T3 and T4 products ($p<0.05$). Contrary, the T3 and T4 products induced the activation of AU25 and all the AUs located on the lower quadrants of the biplot during all the olfaction task (i.e., AU06, AU05, AU01, AU17, AU14, AU26, and AU24). During this task, greater changes in the SCR were obtained for the T4 sample at initial times of exposure, but for T3 product during the last time of olfaction. Additionally, liking was related to the activation of AU43 and AU20, whereas to the deactivation of AU14 and AU17.

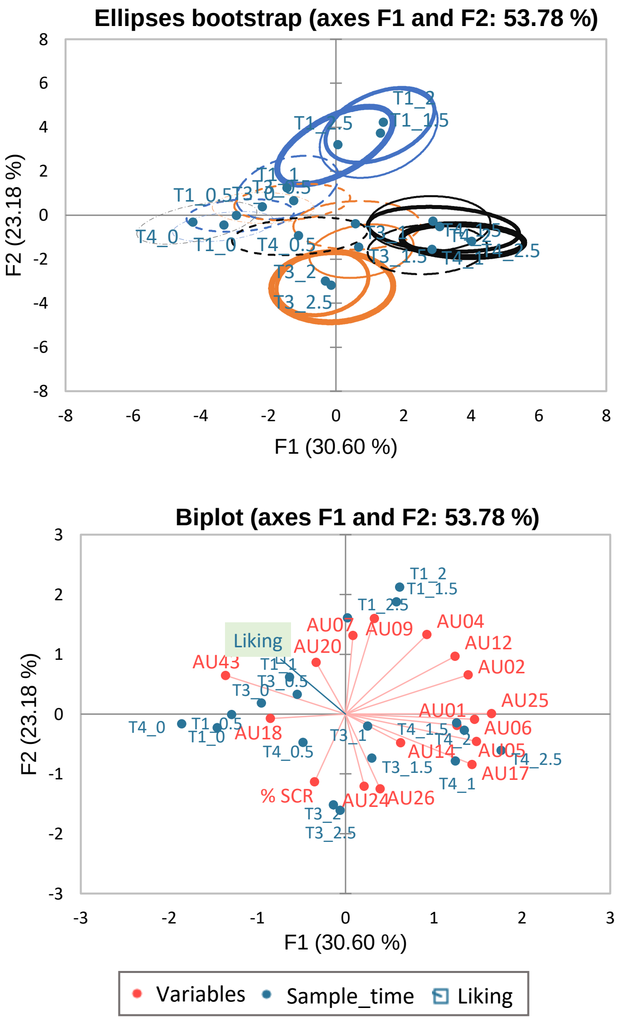


Figure 26. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.1.3. Manipulation

The three liquid food products evaluated in this study induced completely different profiles of AUs activation during the manipulation of the samples at a conscious level (Figure 27). The only exception was obtained for the first 500 ms for which the T1 and T3 samples were not discriminated. The location of the AUs in the biplot suggested that the three samples induced the unconscious activation of AU05 from the start of the manipulation task, but also AU14 in the case of the T1 and T3 samples. While the time of manipulation progressed, the T4 product evoked the conscious activation of the AUs located in the upper-right quadrant of the biplot (i.e., AU23, AU24, AU02, AU04, AU43, AU17, AU26, and AU15), but also probably AU07 and AU20 for the last 500 ms. Opposed, the T1 and T3 samples elicited the activation of the AUs placed in the lower quadrants of the biplot (i.e., AU25, AU01, AU12, AU06, AU07, and AU20) and greater changes in SCR. The location of liking in the biplot suggested that the physiological activation was positively associated with liking as well as the activation of AU23 was negatively related to food acceptance.

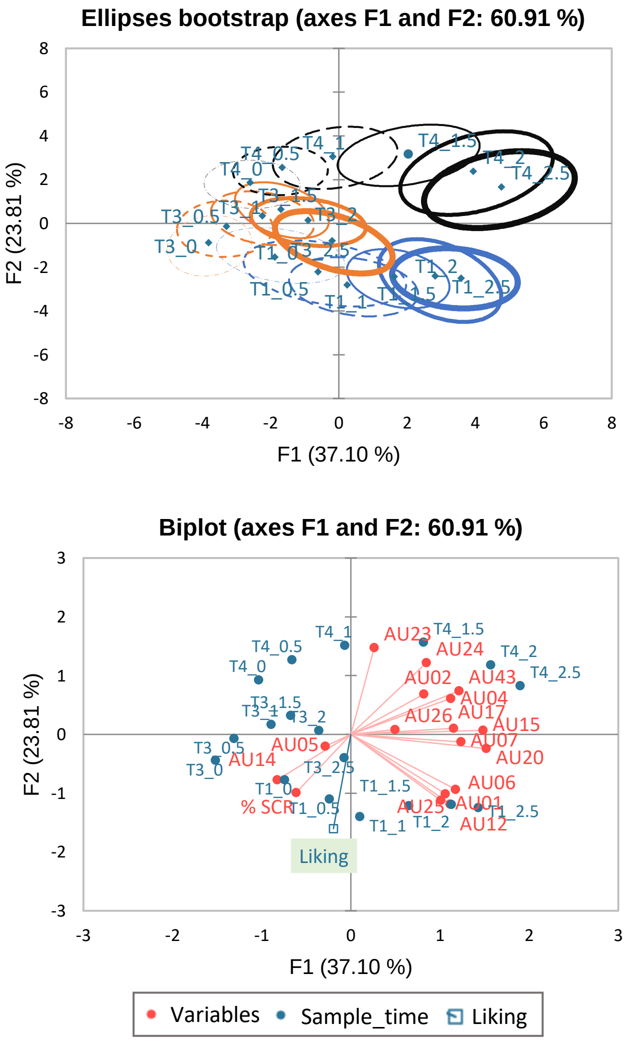
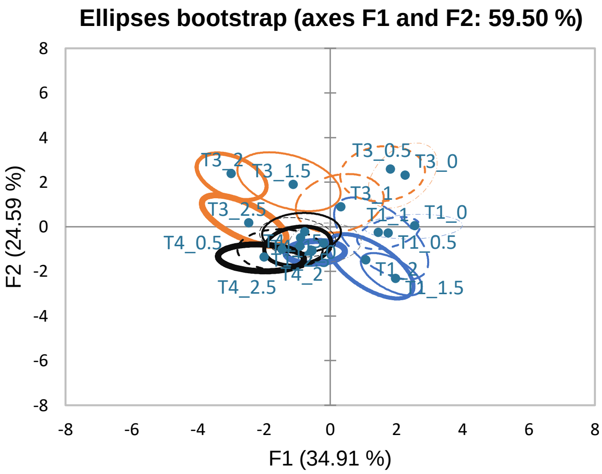


Figure 27. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.1.4. Consumption

During the consumption task (Figure 28), discrimination among samples was only obtained in consciousness (at 500-1000 ms and 1500-2500 ms after the beginning of the consumption). Additionally, from the first 500 ms, the T3 sample induced a different unconscious activation of AUs compared to T1 and T4 ($p<0.05$). The T3 sample elicited the activation of a varied range of AUs during the whole time of consumption, from the activation of AU05 at an initial time to AU02, AU01, AU04, and AU07; and greater changes in SCR. Contrary, the T1 and T4 sample elicited the activation of AU06 and AU43, but of AU07 while the time of consumption progressed. The physiological activation as well as the display of AU05 and AU43 were positively associated with liking during the consumption of the liquids, but the activation of AU02 was negatively related to food acceptance.



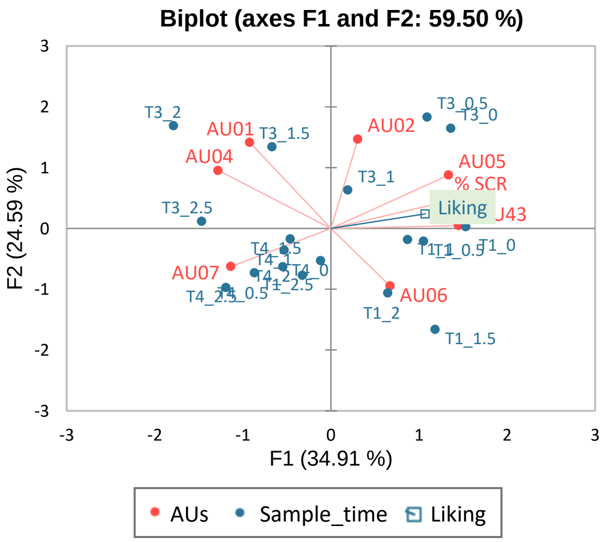


Figure 28. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the consumption of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.2. Codification of basic emotion

The facial expression of the participants was analysed with FaceReader 8.0 to code the basic emotions elicited by the products. The basic emotion data regarding the consumption task was not considered since the codification algorithm of FaceReader 8.0 for all basic emotions rely on the codification of AUs located all over the face, part of which can be altered during the oral processing of food products (Loijens & Krips, 2019). Appendix 4 shows the PCA ellipses bootstrap and biplot obtained for each individual time-range during each task.

4.5.2.1. Observation

During the observation of the products (Figure 29), the emotion elicited by the three samples was only discriminated in consciousness, at the 1000-1500 ms and 2500-3000 ms time-ranges. Additionally, at the 2000-2500 ms from the start of the observation, the T1 sample elicited a significantly different emotional response compared to T3 and T4 (p<0.05). The T1 product elicited a response characterised by disgusted and scared, but also happy and contempt during the last second of observation. Contrary, the T3 and T4 products elicited an unconscious neutral emotion at the beginning, but angry, surprised, and sad while the time of observation progressed. The relocation of T4 sample during the last second of exposure to the upper-right quadrant of the biplot may suggest that this product could also evoke contempt or happy emotion after 2000 ms of observation. Similar to the results obtained for the codification of AUs during the observation of the samples, the T4 product elicited higher changes in the SCR compared to the other samples (p<0.05). The location of liking in the biplot suggested that happy emotion was positively associated with liking, while an increase of the skin response induced lower liking scores during the observation of the products.

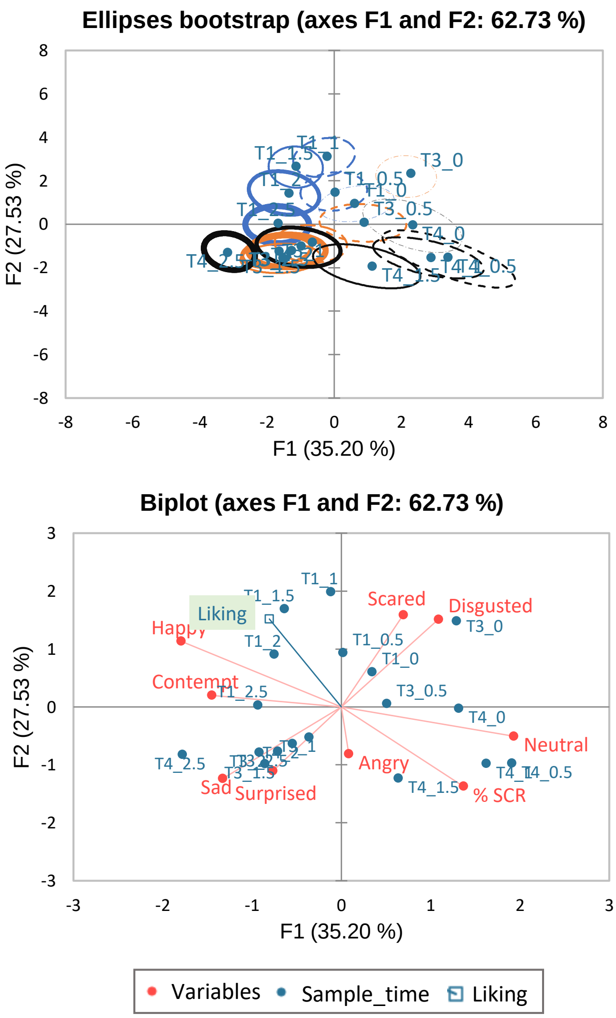


Figure 29. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the observation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.2.2. Olfaction

FaceReader provided low discrimination of samples during the olfaction task (Figure 30). For most part of the olfaction phase, the T1 sample elicited a different emotional response compared to the T3 and T4 product at conscious and unconscious level (time ranges: 0-500, 1500-3000; $p<0.05$, respectively). According to the biplot, the T1 product induced an unconscious sad and scared response at initial time of exposure, which changed into angry, disgusted, surprised, and happy during the olfaction. The T3 and T4 products were completely discriminated in consciousness during the 500-1000 ms and the last 500 ms of exposure (2500-3000 ms). The overlapping of all the ellipses of the T3 sample suggested that this product elicited an emotional response of contempt and neutrality along the time of olfaction. Contrary, the T4 samples elicited a different response over the time of exposure, which changed from an unconscious sad and scared emotion at the beginning to a conscious response of angry, disgusted, surprised, happy, and neutral while the product was smelled longer. During the olfaction task, the T4 and T3 samples induced greater raises of SCR. Sad, disgusted, and angry were positively related to liking, while food acceptance was negatively associated to neutral during this.

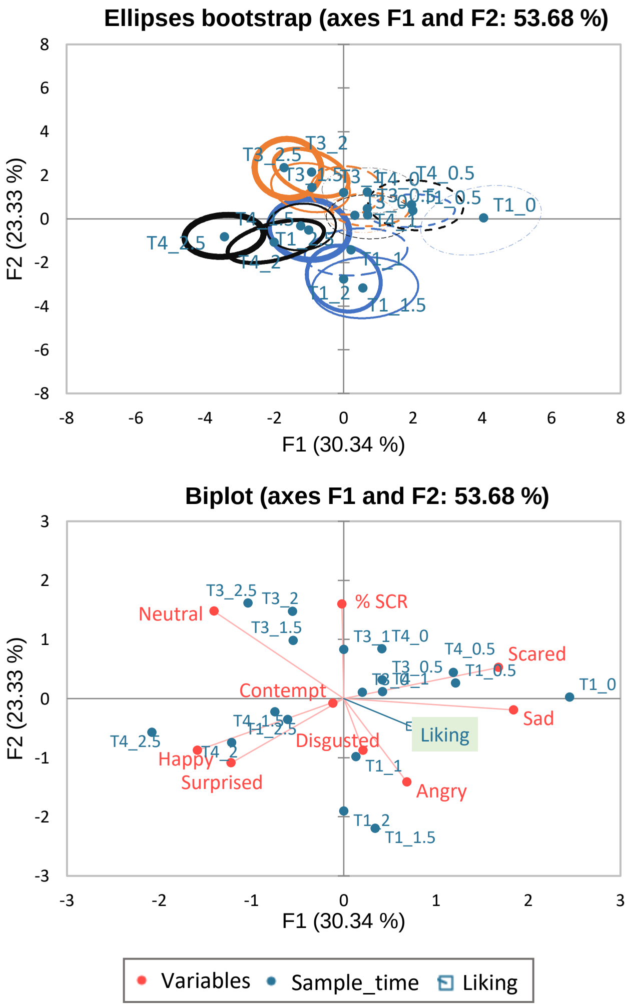


Figure 30. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.2.3. Manipulation

FaceReader 8.0 provided a complete discrimination of the T4 sample during the manipulation task ($p<0.05$; Figure 31). This sample elicited an unconscious emotion of contempt and neutral that consciously changed into angry and disgust while the time of manipulation progressed. On the contrary, the emotional response elicited by T1 and T3 was only differed in consciousness at 500-1000 ms and at 2000-3000 ms. The location of the basic emotions in the biplot suggested that the T1 sample evoked an initial emotion of sad, while the T3 product induced contempt. Later, both samples elicited an emotion characterised by scared, happy, and surprised. During the manipulation of the products, the T1 sample induced greater activation of the SCR. Based on the location of liking in the biplot, results suggested that sad, surprised, scared, and happy were the emotions mainly associated with food acceptance.

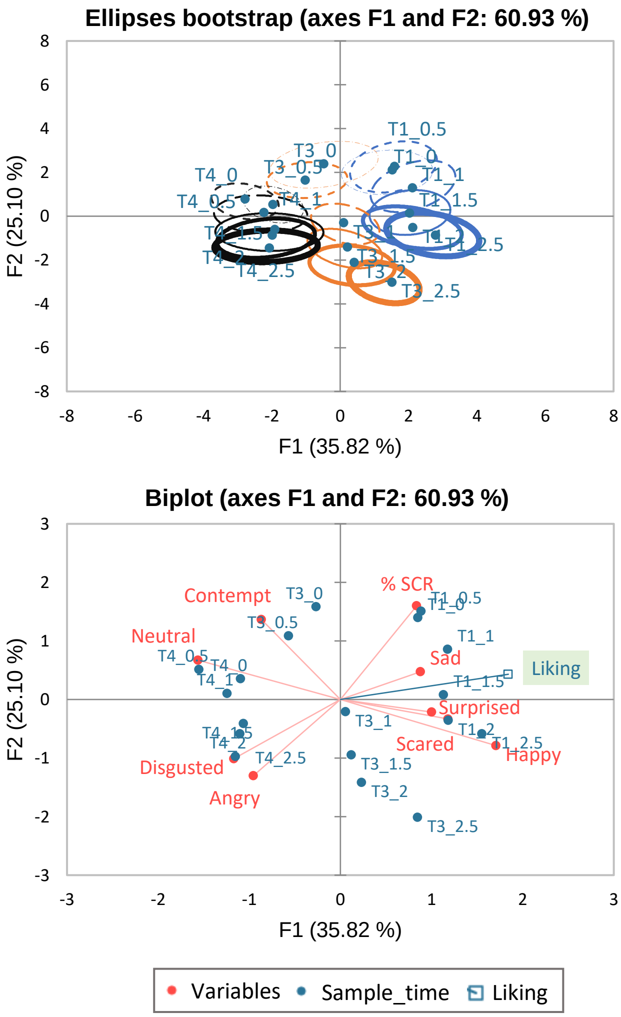


Figure 31. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T1: blue. T3: orange. T4: black. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.5.3. Discussion

Three texture-modified liquid samples elicited a significantly different conscious and unconscious emotional response, evaluated through physiological and behavioural measures, in four traditional sensory tasks (observation, olfaction, manipulation, and consumption).

4.5.3.1. Effect of texture and liking

The observation, olfaction, manipulation, and consumption of an extremely thick product, which was considered neither liked nor disliked (4.4; Study 3, section 4.3.1.) induced negatively valenced emotion characterised by the display of facial expressions related to fear, anger, sadness, disgust as well as surprised according to the Basic Emotion Theory (Ekman et al., 2002a). Contrary, the moderately and the slightly thick liquids, which were liked by the children (5.3 and 5.0, respectively; Study 3, section 4.3.1.), evoked a behavioural response associated with both positive and negative expressions (i.e., angry, fear, disgust, sadness, and happy according to Ekman et al. (2002)) during the observation, olfaction, and manipulation of the samples. A previous study conducted on the same samples (Study 3, section 4.3.) showed that the thickest liquid also evoked a negative emotion but, contrary to the results showed in the current study, the thinner samples elicited a clear positive response measured with an emoji-based questionnaire. The results reported in this Study 5 partially confirmed the findings reported by other authors on the possible associations between facial expressions and liking or disliking.

Studies with schoolchildren and adults suggested that disliked food products elicit a more frequent display of negative expressions, whereas liked and neutrally-liked products evoke an emotional response characterised by positive, neutral, and negative expressions (Danner, Sidorkina, et al., 2014; de

Wijk et al., 2012; He et al., 2014; Horio, 2003; Samant et al., 2017; Zeinstra et al., 2009). The explanation behind this theory relied on the belief that children display more, longer, and more intense facial expressions in response to unpleasant stimuli compared to pleasant stimuli (Soussignan & Schaal, 1996; Zeinstra et al., 2009). Additionally, de Wijk et al. (2012) hypothesised that schoolchildren are too old to display the extreme facial expressions that are frequently observed in babies in response to liked and disliked foods, what hinders their recognition.

On this regard, our results confirmed that liked products elicited an unclear pattern of facial expressions characterised by both positive and negative expressions measured as AUs and basic emotions. On the other hand, and contrary to Zeinstra et al. (2009) findings, even though the thicker sample evaluated in our study was neutrally liked, it evoked negative facial expressions rather than a combination of positive, neutral, and negative reactions. These differences between both studies might have three possible explanations. Firstly, an contrary to our procedure, Zeinstra et al. (2009) studied seven different liquids, part of which could evoke strong reactions in the schoolchildren (e.g., bitter solution), what could have induced mild expressions in neutrally liked products for comparison among samples. Secondly, the three liquid samples included in our study were evaluated in a fixed order starting with the slightly thick sample and ending with the extremely thick product. Thus, a presentation order effect could have influenced our results making the thicker sample more negative than expected also for simple comparison among products. Lastly, schoolchildren prefer homogeneous and simple textures that are easier to manipulate in the mouth (Laureati et al., 2017; Werthmann et al., 2015). Therefore, the thicker texture could have triggered implicit and explicit negative expressions that did not match the explicit liking rating. Subtle spontaneous facial expressions were measured during the study (generally with intensities of activation below 0.1 in a range from 0 to 1 (data not shown)), possibly not being intense enough to trigger a conscious disliking response.

Additionally, the emotional activation induced by the samples seemed to be dependent on the sensory task performed. Until now, the emotional connotation of ANS responses and the effect of pleasant and unpleasant stimuli on the skin conductance response has been largely debated reaching inconclusive results (de Wijk et al., 2012; He et al., 2012; Samant et al., 2017). One theory established that increases in SCR could be associated with negative emotions like anger, anxiety or disgust, but also with positive emotions such as anticipated pleasure (Kreibig, 2010). Our findings were in line with Kreibig (2010) conclusions since the less liked sample evaluated in our study elicited a negatively valenced response and an emotional activation during the first task performed (the observation of products). Contrary, the liked products, which evoked a positive and negative response, induced a greater emotional activation during the tasks that were carried out after the observation (olfaction, manipulation, and consumption), response that could be related to anticipated pleasure.

4.5.3.2. Effect of the sensory task performed

The three samples induced a different emotional response in each task, but the physiological and behavioural response was better discriminated during the manipulation of the products. This result could have been influenced by the fact that the three samples were sensorially similar in colour, taste, and flavour, only differing in texture. Therefore, the differences among samples might have been better evidenced during their manipulation compared to the simple observation and olfaction (see the images of the products in Study 3 (section 3.2.2.3.). To the authors knowledge, this is the first study that evaluated the emotional response elicited by the manipulation of food products. Contrary, other studies examined the emotional responses to the sight, smell, and taste of liked and disliked foods (de Wijk et al., 2012) as well as to the sight and taste of very different breakfast drinks (de Wijk et al., 2014). These authors obtained a more intense emotional response elicited by the smell and taste compared to the sight of the products.

In our study, the behavioural response elicited by the consumption of the products was only evaluated through the codification of AUs that are not influenced by the movement of facial muscles during the in-mouth manipulation and chewing actions (see the following references to identify the facial muscles involved in oral proccesing of food: Epstein & Paluch, 1997; Gamboa et al., 2019; Hanawa et al., 2008; Shiratori et al., 2021; Takada et al., 1994). Other authors already highlighted that the evaluation of facial expressions during the in-mouth manipulation and chewing actions could led to failure and misclassification (Lagast et al., 2017; Samant et al., 2017; Zeinstra et al., 2009). Our findings suggested that the codification of the AUs located in the upper side of the face were sufficient to discriminate liquid samples that only vary in texture during their consumption. Future work could confirm if the codification of the AUs located on the upper side of the face provide good discrimination of samples during other sensory tasks beyond consumption. These results could be promising since lower and middle parts of the face are thought to be more easily controlled by voluntary actions (Soussignan & Schaal, 1996), what could make facial coding a more reliable method.

4.5.3.3. Implicit and explicit measures

While the measure of skin conductance response is considered an implicit response of the ANS activity, facial expressions can be implicitly and explicitly displayed depending on the level of consciousness involved. The analysis of data in time-ranges instead of as a continuous variable allowed us to differentiate the implicit and explicit response displayed by the children. Our results showed that the liquid samples induced different changes in the implicit measure of the emotional activation (changes in SCR) and the facial expressions at an unconscious level (i.e., for the first 500 ms after the event) during all the tasks conducted. Similarly, differences in the facial expressions displayed by the children at a conscious level (i.e., for the 500-3000 ms after the event) were obtained during the four tasks evaluated.

The display of unconscious facial expressions may rely on survival reasons, with the objective to provide important information to prevent potential risks such as the ingestion of poisoning substances (de Wijk et al., 2012; Zeinstra et al., 2009). On this regard, de Wijk et al. (2012) reported that the smell and the taste of food products are potentially more risky than the observation. Consequently, a more intense response and bigger differences among samples could be expected during the olfaction and consumption, but also probably during the manipulation of food products.

On the contrary, it is though that the facial expressions displayed in consciousness can be voluntarily controlled with the ultimate purpose to support communication in social settings (Cernea & Kerren, 2015; Song et al., 2016). However, it could be appropriate considering that the facial expressions displayed by the children in this study provided emotional information and do not seek to support communication because the experimental protocol was designed to minimise social interaction during the evaluation of the products. A modulation effect of the facial expressions displayed by children as young as 5 yrs was reported by Soussignan & Schaal, (1996) during the evaluation of liked and disliked odours.

4.5.3.4. Similarities and differences between the AUs and basic emotion codification

A previous study (Study 4 of this dissertation, section 4.4.) showed that FaceReader 8.0 had better recognition ability for the emotional valence, measured through basic emotions, rather than for individual AUs displayed in spontaneous expressions. However, despite the differences in the software accuracy for AUs and basic emotions, the biplots displayed along this paper suggested that there was a positive association between the codification of positive and neutral AUs and the basic emotions spontaneously displayed by schoolchildren. The positively valenced AUs considered in this study (i.e., AU06+12, AU12+25, and AU24+25; see section 3.4.4. for a description) were placed in similar locations than the happy basic emotion in the observation, olfaction, and manipulation tasks. Similarly, the neutral AUs (i.e., AU06, AU17, and AU18; see section 3.4.4.) were placed in similar locations than neutral discrete emotion in the olfaction task. Contrary, no associations between negative AUs and negatively valenced emotions could be established with the statistical analysis conducted in this study. Further analysis (e.g. PLS regression) could be performed to identify patterns of spontaneous AUs activation associated with each basic emotion.

4.6. Study 6. Children's physiological and behavioural response during the observation, olfaction, manipulation, and consumption of texture-modified solids

Following the same structure than the Study 5 of this dissertation (section 4.5.), the description of the results obtained in the current study were divided in two subsections to better report the results the differences obtained when AUs and basic emotions were independently coded.

4.6.1. Codification of AUs

The 20 AUs measured with FaceReader were considered for a PCA conducted on the observation, olfaction, and manipulation data. Nevertheless, only the AUs located in the upper side of the face were included in the PCA performed on the consumption data to prevent artifacts caused by chewing actions. Appendix 5 shows the PCA ellipses bootstrap obtained for each individual time-range during each task.

4.6.1.1. Observation

The T6 sample elicited a significantly different activation of AUs compared to the T7.1 and T7.2 products ($p<0.05$) at an unconscious and conscious level during all the time of observation ($p<0.05$, respectively; Figure 32). The T6 product induced the activation of AU07 at the beginning of the task, but the activation of all the AUs located on the right quadrants of the biplot (i.e., AU04, AU02, AU14, AU27, AU05, AU25, and AU12) while the product was longer observed. This sample also elicited a higher increase in SCR compared to the other products ($p<0.05$). Contrary, the T7.1 and T7.2 samples evoked a different AUs activation only in consciousness, at 1000-1500 ms ($p<0.05$). Both products elicited the activation of AU01, AU06, AU23, AU15, and AU26 during all the observation. The location of liking in the biplot suggested that this variable was positively associated with the T6 sample, the activation of AU02, AU04, AU14, AU05, AU27, and AU25, whereas negatively related to the AUs placed on an opposite location in the biplot (e.g., AU06).

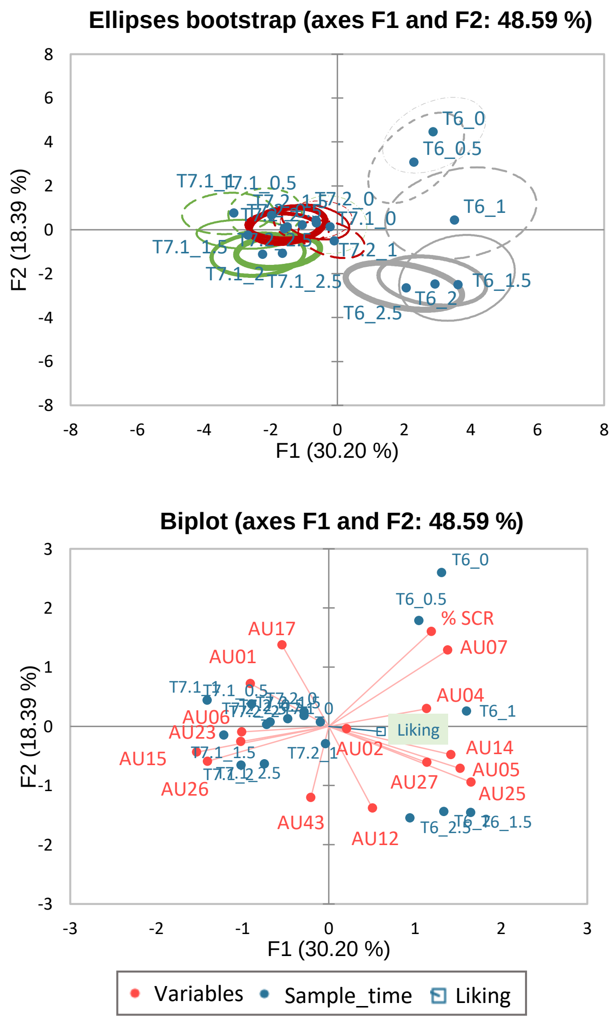


Figure 32. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the observation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.1.2. Olfaction

The overlapping of the 95%-ellipses of confidence pointed out to low discrimination of samples during the olfaction task (Figure 33). Differences were only found at a conscious level between 1000-2500 ms after the olfaction began. At this time, the T6 sample induced the activation of AU23 and AU20, but also greater increases in the SCR. The activation of AU06, AU15, AU04, AU12, and AU01 was evoked by the T7.1 product during the same period of exposure. Contrary, the T7.2 sample mainly induced the activation of the AUs located at the centre of the biplot (e.g., AU14 and AU27). During the olfaction task, the liking of the products tested was positively associated with AU24, AU17, and AU14, but negatively related to the activation of AU07. Based on the location of liking in the biplot, no clear association could be established between liking and the samples tested during the olfaction.

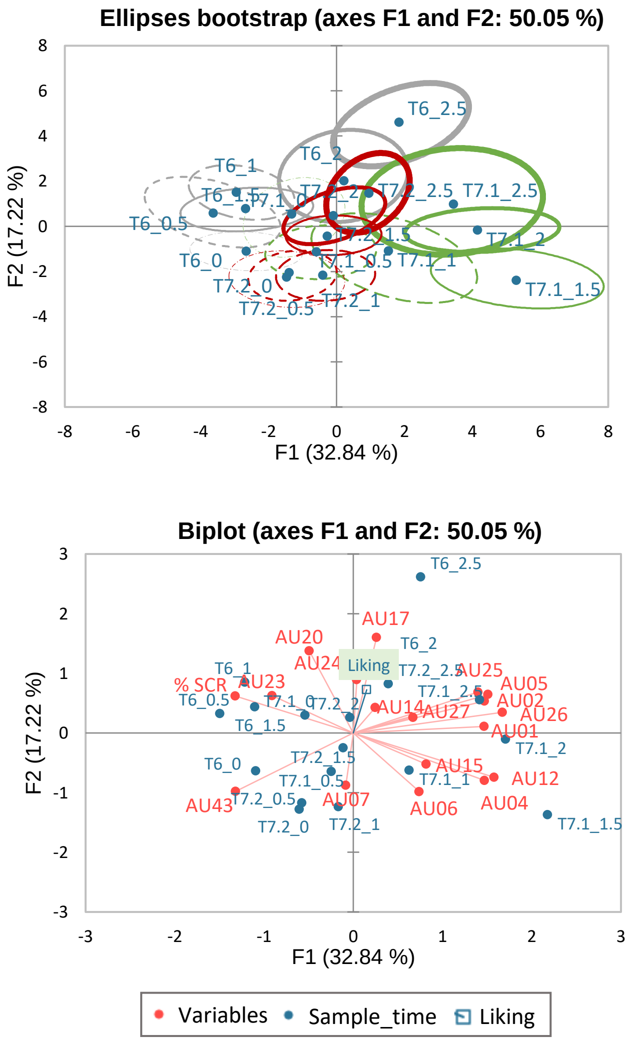


Figure 33. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.1.3. Manipulation

During the manipulation of the products (Figure 34), the three samples elicited a significantly different profile of AUs activation in consciousness, after 1500 ms of exposure (p<0.05). During the first milliseconds of exposure, the three products induced the activation of AU17 and raised the SCR (p>0.05). However, while the time of manipulation progressed, the T7.2 sample elicited the activation of most AUs located on the upper quadrants of the biplot (i.e., AU14, AU09, AU18, AU26, AU20, AU01, AU05, and AU02). On the other hand, the T6 and T7.1 samples evoked significant differences in AUs activation only after 2000 ms of manipulation (p<0.05). T6 elicited the conscious activation of AU15, AU12 and AU43, whereas the T7.1 product consciously activated AU07, AU24, AU06, AU27, AU04, AU23, and AU25 during the last second of evaluation. During this task, liking was positively associated with the T6 sample, the activation of AU15, AU12, and AU43 as well as negatively related to the AUs located in the opposite position in the biplot (e.g., AU14 and AU09).

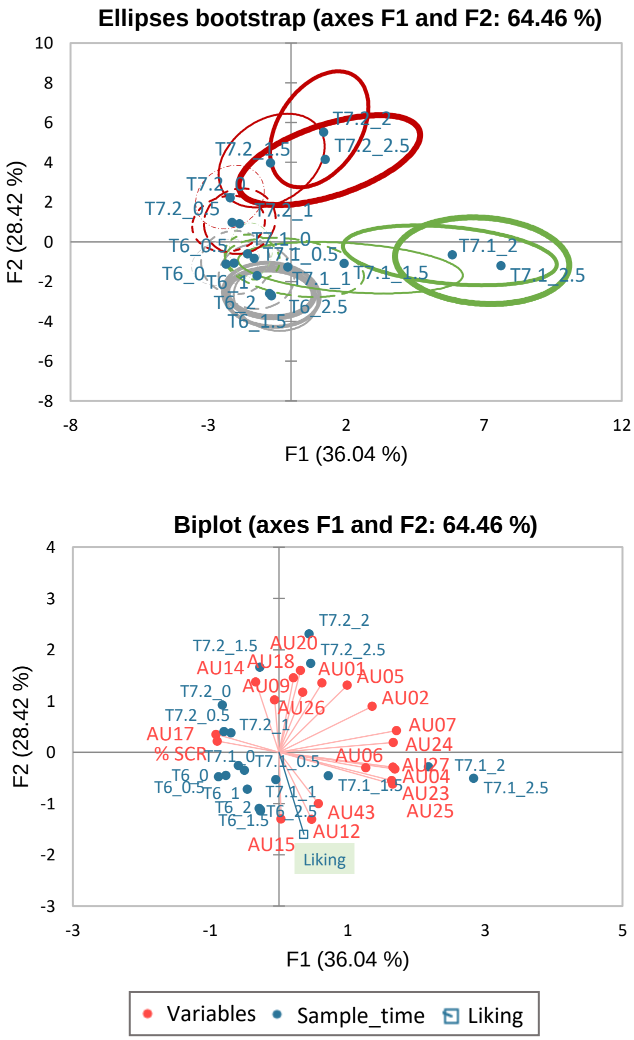


Figure 34. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.1.4. Consumption

The T7.2 product elicited a significantly different AUs activation compared to the other samples ($p<0.05$) at conscious and unconscious level during the consumption (Figure 35). This product induced the unconscious activation of AU01 after it was placed on the mouth, but the conscious activation of AU05, AU04 and AU43 while the sample was consumed. Contrary, the T6 and T7.1 products were discriminated only during the first time-range considered (0-500 ms) and the last second of evaluation (2000-3000 ms). T7.1 elicited a mainly activation of AU07, while T6 induced the activation of AU06, AU02 and a greater increase in SCR. During the consumption of the products, liking was positively related to the T7.1 sample, the activation of AU07, but negatively associated with the activation of AU04 and AU05.

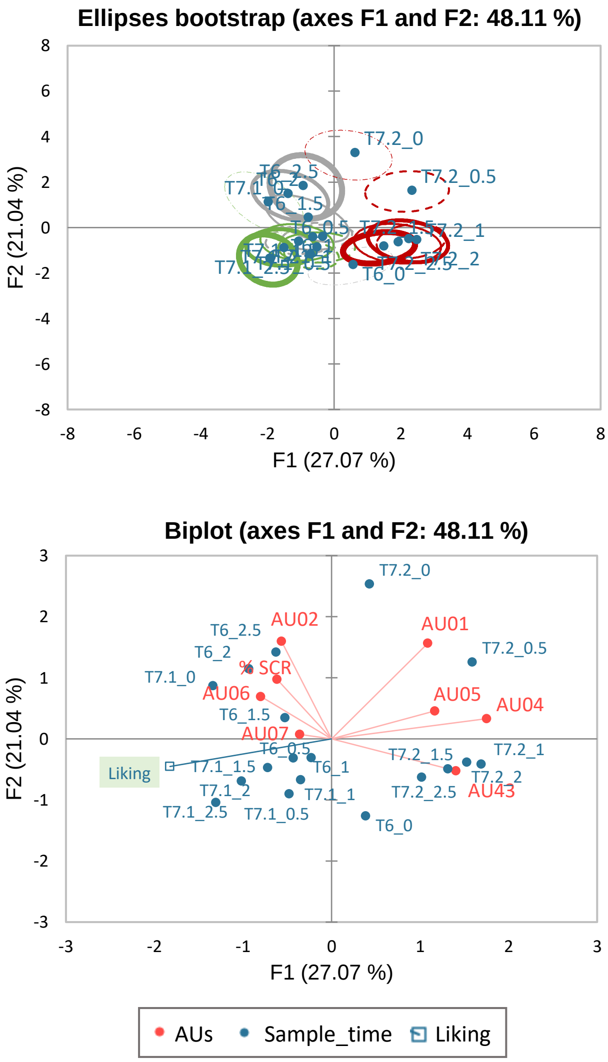


Figure 35. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the consumption of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of AUs was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.2. Codification of basic emotion

A PCA based on the basic emotion data was conducted for the observation, olfaction, and consumption tasks, but not for the consumption. As reported in the Study 5 of this dissertation (section 4.5.), the codification algorithm of FaceReader 8.0 for all basic emotions rely on the identification of AUs located in the upper, middle and lower parts of the face, which include AUs that can be altered with the movement of facial muscles during the chewing and oral processing of food products (Loijens & Krips, 2019). Appendix 6 shows the PCA ellipses bootstrap and biplot obtained for each individual time-range during each task.

4.6.2.1. Observation

The observation of the products induced an equivalent emotional response during all the time of observation (Figure 36), except for the T6 sample which evoked different emotion at a conscious level for times of exposure between 1500 to 3000 ms ($p<0.05$). All samples induced scared during the first second of observation. After 1500 ms, the T6 product evoked surprised, angry, happy, and contempt. T6 also induced greater increases of SCR compared to T7.1 and T7.2 ($p<0.05$). Opposed, T7.1 and T7.2 evoked an equivalent emotional response ($p>0.05$) at a conscious and unconscious level, characterised by emotion of disgusted, neutral, and sad. The T6 sample, increases in SCR as well as the emotion of surprised, angry, happy, and contempt were positively associated with liking during the observation of the products.

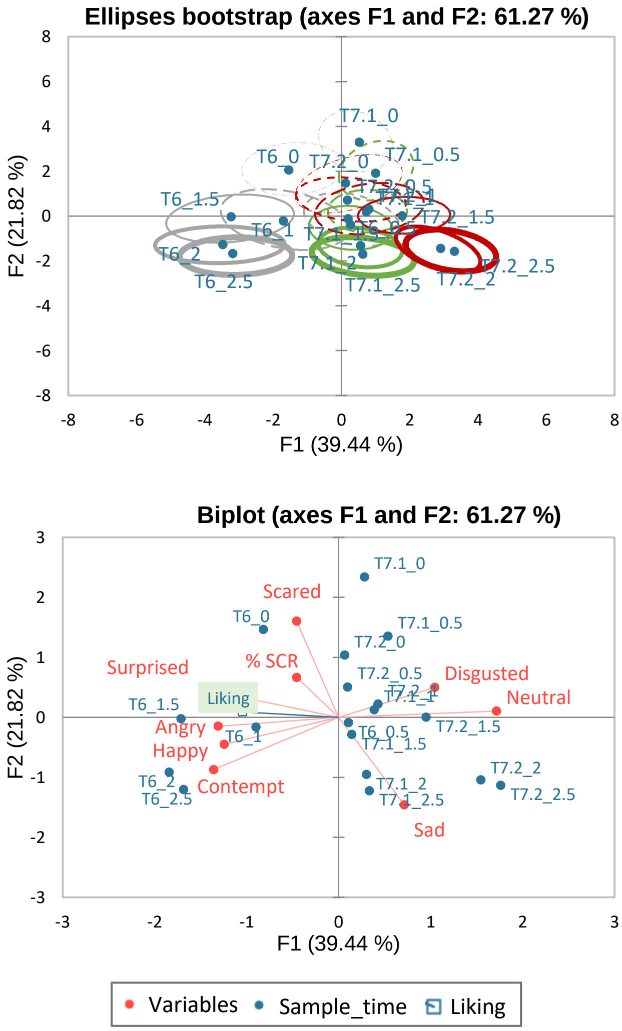
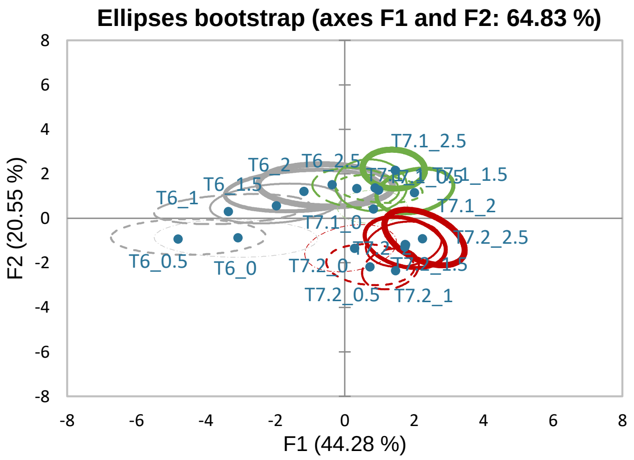


Figure 36. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the observation of the samples. Liking (Study 3 of this dissertation, section 4.3.1.) was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.2.2. Olfaction

During the olfaction task (Figure 37), the T7.2 sample evoked a significantly different emotional response compared to the other products ($p<0.05$), but only in consciousness. The T7.2 sample induced contempt, disgusted, neutral, and angry emotion during the task. Contrary, T6 and T7.1 elicited a significantly different emotional response only for the first 1500 ms of evaluation ($p<0.05$). At the beginning of the olfaction, both samples evoked unconscious emotion of sad and happy, as well as greater increases in SCR, but surprised and scared emotion while the time of olfaction progressed. According to the biplot, liking was negatively associated to disgusted and contempt during the olfaction task, but positively associated with the T6 product.



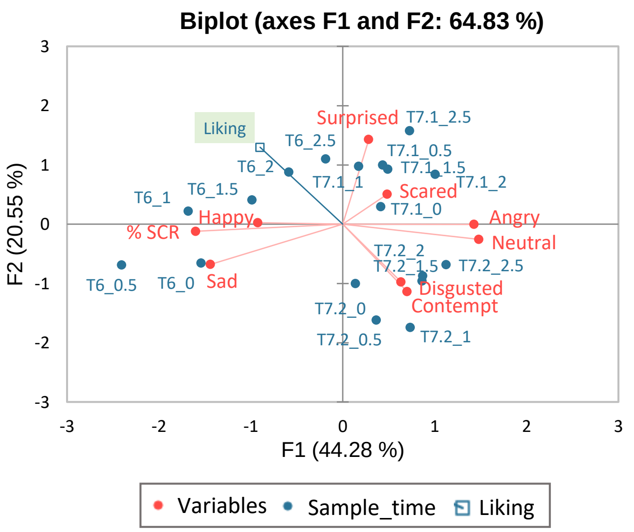


Figure 37. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Liking was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.2.3. Manipulation

The T7.1 sample evoked a significantly different profile of AUs activation during the manipulation task at unconscious and conscious level ($p<0.05$; Figure 38). This product induced sad at the beginning of the task, but disgusted, surprised, and scared while the sample was longer manipulated. Contrary, the T6 and T7.2 products elicited an equivalent emotional response that could only be discriminated in consciousness, at 1500-2000 ms of manipulation. Both samples evoked the emotion located in the lower-right quadrant of the biplot (i.e., neutral and contempt) and a greater activation of SCR at initial time-ranges. T6 was characterised by the elicitation of sad, while the T7.2 product induced angry and happy response. During the manipulation task, liking was positively related to the T7.1 sample and sad emotion, but negatively associated with increases in SCR.

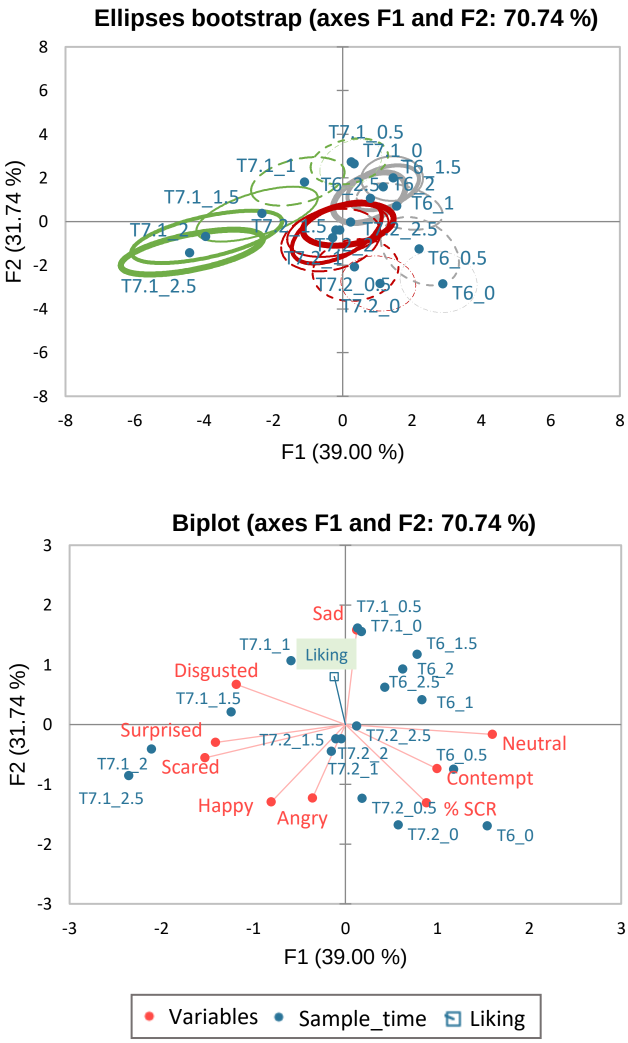


Figure 38. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Liking was included in the analysis as a supplementary variable. The codification of basic emotions was performed by FaceReader 8.0. In the ellipses bootstrap plot, the shape and thickness of the lines corresponds to the evolution of the time of exposure. Initial times of exposure are represented with dotted and thin lines, while longer times of exposure correspond to continuous and thicker lines. T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges appear in each plot as follows: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

4.6.3. Discussion

Three texture-modified solid samples elicited a significantly different conscious and unconscious emotional response, evaluated through physiological and behavioural measures, during four traditional sensory tasks (observation, olfaction, manipulation, and consumption).

4.6.3.1. Effect of texture and liking

The hardest solid product evaluated in the study (T7.2) induced negative emotion during the observation, olfaction, manipulation, and consumption characterised by the displayed of facial expressions related to fear, anger, and sadness as well as surprised according to the Basic Emotion Theory (Ekman et al., 2002a). Contrary and during all the tasks performed, the soft (T6) and easy to chew (T7.1) products evoked a behavioural response associated with positive, negative and neutral expressions (i.e., angry, fear, sadness, and happy according to Ekman et al. (2002)).

Most research done on the effect of liking/disliking on facial expressions was conducted on products and odours that elicited a varied range of acceptance (de Wijk et al., 2012; He et al., 2014; Samant et al., 2017; Zeinstra et al., 2009). These authors agreed on the fact that disliked products induce negative facial expressions that are easily recognise, but no clear pattern of expressions is displayed for liked products. Taken together our results and these authors' findings, we can consider that the hardest sample evaluated in our study elicited a behavioural response typically associated with disliked foods even though it was considered neither liked nor disliked by the children. Additionally, the results obtained for the soft and easy to chew products suggested that both samples induced the facial expressions traditionally associated with liked foods even though they were also considered neither liked nor disliked by the children. The findings obtained in our study support results concerning texture-modified solid samples that did not vary in colour, odour, and flavour (Study 3 of this dissertation; section 4.3.1.), which showed that the softest solid sample elicited a less negative emotional response than the hardest one in a test conducted with an emoji-based tool. Additionally, in line with these results, the evaluation of the implicit and explicit emotional response evoked by liquid textures showed that products with a thinner texture induced more positive expressions than thicker ones (Study 5, section 4.5). The differences obtained in the emotional response elicited by the samples could be expected from the texture point of view since schoolchildren prefer homogeneous and simple textures that are easier to manipulate in the mouth (Laureati et al., 2017; Werthmann et al., 2015). Additionally, recent papers classified the Spanish children as soft-likers (Laureati et al., 2020) and concluded that the soft texture was a key attribute for preference in solid foods such as biscuits (da Quinta et al., 2021).

Until now, the emotional connotation of ANS responses and the effect of pleasant and unpleasant stimuli on the skin conductance response has been largely debated reaching inconclusive results (de Wijk et al., 2012; He et al., 2012; Kreibig, 2010; Samant et al., 2017). The findings obtained in a previous study (Study 5, section 4.5.) showed that the emotional activation induced by liquid samples with varied textures depended on the sensory task performed. Contrary, the current study pointed out that the solid product that elicited a more positive emotional response was associated with changes in SCR whatever the sensory task was. Other authors associated increases in SCR with both liked and disliked foods (de Wijk et al., 2012; Kreibig, 2010). Kreibig (2010) suggested that the activation of SCR could be related to emotion of amusement, joy, and anticipatory pleasure (only when the stimulus is visually present) (Kreibig, 2010).

4.6.3.2. Effect of the sensory task performed

Opposed to the discrimination ability obtained in a previous work with liquid samples (Study 5, section 4.5.) the combination of the facial coding and the measure of skin conductance response in solid foods showed a good sample discrimination during all the sensory tasks performed.

This result was unexpected since the three samples evaluated were apparently similar (see the pictures of the products in section 3.2.2.3.) what we thought would lead to similar patterns of facial expression and low discrimination. We expected greater changes in SCR, the display of more intense expressions, and therefore, greater sample discrimination during the manipulation and consumption tasks because texture differences would have been more evidenced during the in-hand manipulation and oral processing actions. Nevertheless, the good sample discrimination obtained among samples might suggest that texture differences were more pronounced than expected and that children perceived them even during the observation task. On the other hand, greater sample discrimination could have been obtained during the manipulation and consumption tasks if an standard method would have been used to evaluate the samples. On this regard, it is noteworthy to mention that the softest sample (T6) was manipulated and consumed with the help of a spoon instead of the fingers because in a pre-test children showed difficulties in handling the product.

In our study, the behavioural response elicited by the consumption of the products was evaluated following the same approach than for liquid samples (section 3.4.4.). Only the codification of AUs located in the upper side of the face, AUs not influenced by the movement of facial muscles during the in-mouth manipulation and chewing procedures, was considered (see the following references to identify the facial muscles involved in oral proccesing of food: Epstein & Paluch, 1997; Gamboa et al., 2019; Hanawa et al., 2008; Shiratori et al., 2021; Takada et al., 1994). Similar to previous results (Study 5; section 4.5.), our current findings suggested that the codification of the AUs located in the upper side of the face was sufficient to discriminate solid samples from the same product category that only vary in texture during their consumption. These results outlined that facial coding is a suitable method to also be used in tasting experiences, and the codification of specific regions of the face could be a promising approach to overcome the limitations caused by artefacts during chewing actions.

4.6.3.3. Implicit and explicit measures

The solid samples evaluated in this study induced different implicit responses (i.e., SCR and facial expressions measured during the first 500 ms of exposure) during the observation, olfaction (only changes in SCR), manipulation, and consumption tasks. Additionally the three solid samples elicited a different explicit response (i.e., facial expressions measured during the 500-3000 ms of exposure) during the four tasks evaluated.

These results are in total accordance with the findings reported in a previous study (Study 5, section 4.5.) in which different implicit and explicit responses were induced by liquid foods of the same product category during their observation, olfaction, manipulation, and consumption.

4.6.3.4. Similarities and differences between the AUs and basic emotion codification

In this study, an agreement was obtained between the codification of positive and neutral AUs and basic emotions with FaceReader 8.0. The positive AUs considered in this study (i.e., AU06 + 12, AU12 + 25, and AU24 + 25; see section 3.4.4.) were placed in similar locations than the happy basic emotion during the observation, olfaction, and manipulation tasks. Additionally, the neutral AUs (i.e., AU06, AU17, and AU18; see section 3.4.4.) were placed in similar locations than neutral discrete emotion during the observation and olfaction task. These results confirmed the findings obtained in a previous work (Study 5, section 4.5.), suggesting that FaceReader provides similar emotions profiles for neutrally and positively valenced emotions when the spontaneous facial expressions elicited by food textures are analysed as AUs and basic emotions. Contrary, different results were obtained when negative AUs and basic emotions were coded, and further statistical analysis could be necessary to identify patterns of negative expressions.

5. General Discussion

Emotions are thought to have a multicomponent character (Coppin & Sander, 2016). According to this basis, the different levels of emotional processing (i.e., unconscious, early cognition, and conscious) should be evaluated in order to reach an holistic perspective of the emotion (Kaneko et al., 2018). Combinations of methodologies that include cognitive, physiological, or behavioural responses have been mainly used in the last decade to examine the emotion elicited by food and odours in adult population (de Wijk et al., 2012, 2014; He et al., 2012; He, de Wijk, et al., 2016; Samant et al., 2017). On the other hand, to the authors knowledge, only de Wijk et al. (2012) applied a combination of physiological and behavioural responses in children to evaluate the emotion elicited by the sight, the smell, and the taste of food products. On this regard, before evaluating food-evoked emotion in children, researchers should bear in mind that methodologies designed for adult population should not be directly applied in child-centred studies since they should be adapted to their cognitive, physical and social stage of development (Guinard, 2001; Laureati et al., 2015). This dissertation emerged to develop child-friendly methodologies capable of measuring cognitive, physiological, and behavioural responses elicited by food products.

Cognitive methods rely on self-reported responses. Among them, word-based questionnaires were traditionally developed to evaluate food-evoked emotions in adults (Chaya et al., 2015; King & Meiselman, 2010; Nestrud et al., 2016; Spinelli et al., 2014), but were scarcely designed for children, with the exception of De Pelsmaeker et al. (2013) and Jervis et al. (2014). Verbal questionnaires are thought to demand a high cognitive effort and to be inappropriate for groups of population with low capability of reading, such as young children (Comesaña et al., 2013; Köster & Mojet, 2015; Toet et al., 2018). On the contrary, graphical tools emerged as an alternative to word-based methods since they do not rely on verbal responses. Additionally, the evaluation of images requires lower cognitive effort, what made images be faster processed than words (Comesaña et al., 2013). Among graphical tools, emoji have been successfully used in child-centred studies to evaluate the emotional response elicited by written stimuli, images, and tasting experiences (Gallo et al., 2017b; Schouteten et al., 2018; Swaney-Stueve et al., 2018). As Jaeger & Ares (2017) highlighted, understanding how consumers perceive the emoji is necessary to conduct emotion studies accurately, since the emotions portrayed by the emoji are differently perceived depending on sociodemographic factors (age, gender, and country) or the emoji's platform of design (Bai et al., 2019; Jaeger et al., 2019; Rodrigues et al., 2018; Sick, Monteleone, et al., 2020). The first study of this dissertation (Study 1, section 4.1.) emerged to fill this gap since only adults (Jaeger et al., 2019) and preadolescent's (Sick, Monteleone, et al., 2020) perception of emoji were evaluated, but also to provide a basis for future research on emoji-based studies. Our findings pointed out that school-aged children differently perceived facial emoji in dimensional and semantic meaning depending on the gender of the participant as well as the context of evaluation but could also be influenced by the age. These results confirmed previous studies which concluded that facial emoji are not as universal as it was initially thought (Bai et al., 2019; Jaeger et al., 2019; Sick, Monteleone, et al., 2020), and pointed out that special care should be taken when conducting emoji-based studies because the evocation of a food context may change the interpretation and perception of the tool.

Therefore, considering that the dimensional and semantic meaning of the emoji changed when a food related context was evoked, it was hypothesised that certain emoji could have an special association with the food domain. On this regard, Vidal et al. (2016) already identified facial emoji that were more frequently selected to describe food experiences on Twitter as well as Sick, Spinelli, et al. (2020) conducted an study with pre-adolescents to identify a group of emoji with specificity for seven food-related contexts. Nevertheless, most contexts evoked in Sick, Spinelli, et al. (2020) study were positively valenced, only considering "most disliked food" as negative context of evaluation. Therefore, the second study included in this dissertation (Study 2, section 4.2.) was conducted to identify a group of food-specific emoji for a balanced selection of food evoked contexts, which afterwards would be used in studies with schoolchildren. Results showed that 17 facial emoji were specific for the contexts evoked. Similar patterns of specificity were reported for pre-adolescents by Sick, Spinelli, et al. (2020). Far from the belief that emoji could be applicable in a range of contexts, in our work most negative and neutrally valenced emoji only showed specificity for certain situations. Additionally, redundancies in emoji uses were found among positively valenced emoji, as suggested by Sick, Monteleone, et al. (2020).

Once that the emoji-based tool was designed, its applicability in food studies was tested in terms of the ability to discriminate among samples. According to Schouteten et al. (2018) and Swaney-Stueve et al. (2018) an emoji based tool could have limited discrimination ability for samples with equivalent liking perception and for samples that belong to the same product category. Therefore, the applicability of our list of food-specific emoji was intentionally tested with samples that belonged to the same and to different product category as well as with samples that elicited a wide range of expected liking. Three different types of food stimuli were used for this purpose. A first study (Study 2 of this dissertation, section 4.2.) was conducted to evaluate the discrimination ability of the emoji-based tool for food stimuli evoked as food names and images, whereas Study 3 (section 4.3.) was performed on real food samples. This approach was followed since the evocation of different types of stimuli proved to elicit a different emotional response (Cardello et al., 2012; Piqueras-fiszman & Jaeger, 2014).

Direct comparison of the results obtained in Study 2 and Study 3 could not be made because of methodological differences such as the questionnaire layout used (CATA vs. RATA) and the samples tested. Based on the results obtained in Study 2 we concluded that the emoji-based tool provided a good sample discrimination when food products were evoked as written stimuli, while no discrimination was obtained when samples were evoked as food images. As reported in Study 2 this result could have been influenced by the fact that the images used did not represent well enough the specific products involved in the study (e.g., only small pieces of dehydrated fruit were observable in the picture called "biscuit with dehydrated fruit") what might hinder their recognition. Jaeger et al. (2018) also reported that food images may be too specific, what may limit their relevance to some participants and difficult their recognition. Overall, good sample discrimination was obtained when the list of food-specific emoji was displayed in a CATA layout for samples that belonged to the same product category and for samples that elicited an equivalent liking perception. However, limited applicability was observed when samples induced an equivalent liking and arousal response. This study was the first work that highlighted the relevancy of arousal on the discrimination ability of emoji. Therefore, and based on Ares & Jaeger (2017), it was hypothesised that a more complex methodological approach (RATA) could better discriminate among samples that elicited equivalent responses by providing a rating score of the emotion felt.

Due to the similarity of the samples tested in Study 3, which only varied in texture, we expected a similar liking and emotional response. Consequently and based on the hypothesis raised in Study 2, we decided to use a RATA layout instead of CATA to get more insights on children's emotional responses, even though RATA methodology have never been used before with children. Results showed that two out of the six products evaluated in Study 3 were discriminated with the emoji-based tool displayed in a RATA layout. However, the sample configurations obtained per prototype were inconclusive because of the simultaneous presence of positively, neutrally, and negatively valence emoji. These findings could point out that children with different emotional responses were present within the group of participants or that children could have experienced difficulties in rating the intensity of the emotion felt. The former could not be confirmed because a reduced number of subjects participated in the study, what disabled us to conduct a cluster analysis with statistical significance. Regarding the latter, these results were in accordance with the findings reported in Study 1 of this dissertation (section 4.1.) which also suggested that schoolchildren did not fully understand the concept of the intensity of the emotion portrayed by the emoji during the evaluation of their dimensional meaning.

Once that a new cognitive tool was designed for child-centred studies, the effort was focused on the development of a new methodology that combined physiological and behavioural responses for the study of food-evoked emotion. Skin conductance response (SCR) was selected to represent physiological responses, since it is the physiological measure more extensively used in food research (Kreibig, 2010). Similarly, the recognition of facial expressions through automatic facial coding was selected to represent behavioural responses, since facial expressions are considered the primary channel for expressing and communicating emotions (Danner & Duerrschmid, 2018), but also the most studied type of behavioural expression for the study of emotions (Coppin & Sander, 2016). Even though physiological responses of the ANS are thought to be a manifestation of body functions beyond emotional experiences (Spinelli & Monteleone, 2018), ANS responses are generally accepted as indicators of dimensional responses such as arousal or valence (de Wijk et al., 2012; Kreibig, 2010; Spinelli & Monteleone, 2018). On the other hand, the use of facial coding for the measure of emotion presents several limitations that hinder its applicability and question the results obtained (Danner & Duerrschmid, 2018; Spinelli & Monteleone, 2018), such as: (i) the validity of results, (ii) the lack of a context during the codification process, (iii) the social purpose of facial expressions rather than emotional connotation, (iv) the possibility to voluntarily control the activation of facial muscles, and (v) the alteration of the facial expressions during mouth movements associated with the consumption and oral processing of foods.

On this regard, the three last studies of this dissertation (Study 4 (section 4.4.), Study 5 (section 4.5.), and Study 6 (section 4.6.)) aimed to evaluate the recognition ability of a specific facial coding software (FaceReader 8.0) during the recognition of the spontaneous facial expressions displayed in response to food stimuli and to design an experimental protocol that minimise the existing limitations of these methodologies during the evaluation of food products. Therefore, Study 4 was performed to determine the recognition ability of the FaceReader 8.0 software for specific AUs and basic emotions displayed in spontaneous facial expressions. When it was possible, the evaluation of the software's accuracy was evaluated in association with food stimuli and schoolchildren because of the specific purpose to apply this software in child-centred studies. FaceReader 8.0 proved to have similar recognition ability for average AUs than for the emotional valence (coded through basic emotions) when facial expressions were elicited by videos and images, respectively. Similar to Skiendziel et al. (2019) conclusions, our results suggested that FaceReader 8.0 better recognised the facial expressions that are more commonly displayed in everyday life. Emotions evoked by food images were similarly recognised compared to the emotional responses elicited by nonspecific images. Interestingly, the last work conducted in Study 4 (section 4.4.3.) showed that the software had higher accuracy for the recognition of the emotional response induced by real food samples, specially by disliked or unpleasant products, compared to the recognition rates obtained for food images. This finding was not unexpected since, as de Wijk et al. (2012) outlined, more intense responses are expressed during the performance of sensory actions that could be more dangerous and may lead to potentially risky results (e.g., the ingestion of poisonous substances). On this regard, more intense facial expressions were expected during the evaluation of real food samples compared to food images, what may cause a greater recognition rate of facial expressions. The better recognition rates obtained for unpleasant stimuli could be explained because people are more prone to express facial expressions in response to negative stimuli compared to neutral or positive stimuli (Zeinstra et al., 2009), what may facilitate the recognition of negatively valence expressions. Additionally, as Stöckli et al. (2018) highlighted, for simple probability the software had more chances to better categorise negative rather than positive expressions (i.e., FaceReader 8.0 only coded "happy" as positively valenced emotion, but "fear", "sad", "angry", and "disgust" as negative emotion).

Once that FaceReader's ability to recognise the spontaneous AUs and basic emotions elicited by food stimuli was tested, an experimental protocol was designed to apply facial coding and SCR in food studies conducted with schoolchildren. Study 5 and Study 6 of this dissertation detailed the experimental method developed and showed the main results obtained when this protocol was specifically applied during the sensory evaluation of liquid and solid food samples. As it was previously reported for the emoji-based studies (Study 2 (section 4.2.) and Study 3 (section 4.3.) of this dissertation), the applicability of the facial coding and SCR methodology designed was tested in terms of the discrimination achieved among samples. Results showed that the codification of specific AUs and basic emotions led to similar sample discrimination, what could be expected considering that our findings in Study 4 (section 4.4.) showed that FaceReader's ability to recognise the activation of the AUs and the basic emotions was similar. Although Spinelli & Monteleone (2018) and Zeinstra et al. (2009) suggested that facial coding could have limited applicability for products that elicit different liking in the range of food acceptance, our combined methodology based on facial coding and SCR successfully discriminated neutral and liked samples that elicited equivalent and different degrees of liking. Good discrimination among samples was unexpected since liquid and solid food products were intentionally designed to have the same sensory characteristics in terms of taste, flavour, and appearance, but different texture. Even though texture differences among samples were not easily recognised (see the pictures of each texture prototype in section 3.2.2.3.), sample discrimination was obtained at both unconscious (first 500 ms of exposure) and conscious level (until 3000 ms of exposure).

The methodology designed was also appropriate to evaluate food samples during four sensory tasks traditionally conducted in testing experiences. Children were asked to evaluate each product in a sequential order in which each sample was observed, smelled, touched, and consumed with no time restrictions to make the experience more naturalistic. Overcoming one of the main limitations associated with facial coding method, our protocol included information about the context in which facial expressions and SCR activation were displayed. On this regard, the identification of events during the testing sessions allowed us to directly associate an emotional response with the specific action that conducted the response. To our knowledge, only de Wijk et al. (2012) and Rocha-Parra et al. (2016) conducted a similar procedure using the identification of events and a multiple-sip approach, respectively.

Additionally, the codification of specific AUs located in the upper-side of the face allowed us to apply the methodology designed even during the consumption of liquid and solid food products preventing the artifacts caused by chewing and oral processing actions. Until now, other authors tried to prevent the artifacts caused during the consumption of food products with: (i) the evaluation of the facial expressions displayed after finishing the oral processing of the samples involved (Kostyra et al., 2016), or (ii) the codification of posed facial expressions that portrayed the emotion felt during the consumption (Danner, Sidorkina, et al., 2014). Both methodologies lack on the evaluation of the unconscious inherent of the emotion by relying on a measure that was taken after the consumption. Additionally, Danner et al. (2014)'s procedure relied on a retrospective and cognitive evaluation of the emotion felt. To our knowledge, Study 5 and Study 6 of this dissertation are the first work that attempted to apply facial coding in a naturalistic setting during the consumption of food products with the ultimate purpose to prevent the misclassification cause by oral processing actions.

6. Conclusions

1. The emotional meaning of facial emoji is differently understood by schoolchildren depending on their gender and the context of evaluation. Additionally, age has also the potential to influence the emotional meaning of the emoji.

2. A group of facial emoji with specificity for a balanced range of food contexts has been identified. Among them, positively valenced emoji broadly represent the emotions elicited by a general food context as well as liked products. On the contrary, neutral and negatively valenced emoji represent the emotions induced by different degrees of disliking.

3. The list of food-specific emoji previously identified shows applicability for the study of the emotions elicited by written food stimuli and real food samples. On the contrary, the list of food-specific emoji is uncapable of differing the emotional response induced by food samples evoked as images.

4. The applicability of Rate-All-That-Apply (RATA) method in emoji-based studies with children over 5 yrs is inconclusive. Children could have difficulties in understanding the concept of the intensity of the emotion felt.

5. Facial coding proves to be an appropriate method to evaluate the facial expressions evoked by real food samples, especially for unpleasant samples.

6. Food textures influence food-evoked emotions at cognitive, physiological, and behavioural level in schoolchildren.

7. The combination of automatic facial coding and the measure of the skin conductance response is an appropriate method to discriminate the emotional response induced by liquid and solid samples designed to only vary in texture, which elicit both an equivalent and different liking responses.

8. The combination of automatic facial coding and the measure of the skin conductance response has applicability in the study of food-evoked emotions during the observation, olfaction, manipulation, and consumption of liquid and solid foods.

9. The codification of the upper side of the face is a good approach to ensure the correct measurement of facial expressions during the consumption of food products without the artifacts caused by chewing and oral processing actions.

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Appendix

Appendix 1. Selection of images from OASIS database

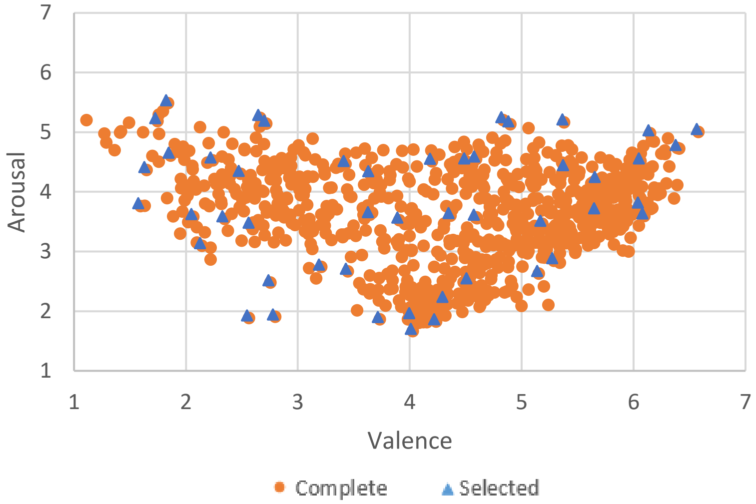


Figure 39. Distribution of the images from the OASIS database in valence and arousal dimensions according to the validation study conducted by Kurdi et al. (2017). Orange round markers represent the images from the complete database. Blue triangles represent the child-friendly images selected for our study.

Table 15. Description of the child-friendly OASIS images selected for our study and the valence and arousal average ratings obtained in the validation study conducted by Kurdi et al. (2017).

Code	Theme	Valence	Arousal
I306	Beach 1	6,39	4,73
I120	Bee 1	3,65	3,61
I380	Bored pose 2	3,21	2,74
I851	Bungee jumping 1	4,20	4,50
I305	Car crash 1	1,87	4,60
I364	Car race 2	4,36	3,59
I385	Cardboard 3	3,73	1,86
I749	Dancing 2	5,18	3,46
I482	Dessert 3	5,67	4,20
I398	Destruction 10	2,07	3,58
I87	Dirt 4	4,01	1,92
I129	Dog 6	6,58	5,00
I759	Dog attack 2	3,43	4,47
I708	Eating 3	5,15	2,62
I124	Explosion 4	2,49	4,30
I670	Explosion 5	1,84	5,48
I860	Feces 1	2,15	3,09

I676	Fire 6	2,24	4,52
I220	Fireworks 2	6,15	4,98
I359	Food 3	5,29	2,84
I290	Food 6	5,66	3,68
I335	Frustrated pose 3	2,35	3,54
I59	Galaxy 7	6,06	4,51
I461	Garbage dump 2	1,59	3,76
I871	Garbage dump 7	2,76	2,47
I725	Gorrila 1	3,91	3,52
I233	Lake 7	6,10	3,59
I857	Lion 2	3,65	4,29
I323	Miserable pose 1	2,58	3,44
I494	Paper 3	4,24	1,82
I309	Parachuting 4	4,84	5,20
I891	Pigeon 5	4,52	2,51
I283	Rocks 3	4,31	2,19
I71	Rollercoaster 2	5,38	5,16
I776	Running away 1	4,59	3,57
I239	Scared cat 1	4,59	4,54
I101	Severed finger 1	1,65	4,36
I830	Sidewalk 6	2,80	1,90
I687	Skydiving 5	4,90	5,13
I630	Snow 4	3,45	2,66
I597	Sunset 1	6,05	3,77
I607	Thunderstorm 6	4,50	4,51
I838	Tiger 2	5,39	4,40
I200	Tornado 4	2,72	5,14
I356	Volcano 2	2,66	5,24
I256	Wall 2	4,03	1,66
I377	War 8	1,75	5,18
I810	Yarn 1	2,56	1,88

Appendix 2. Selection of images from FRIDa database

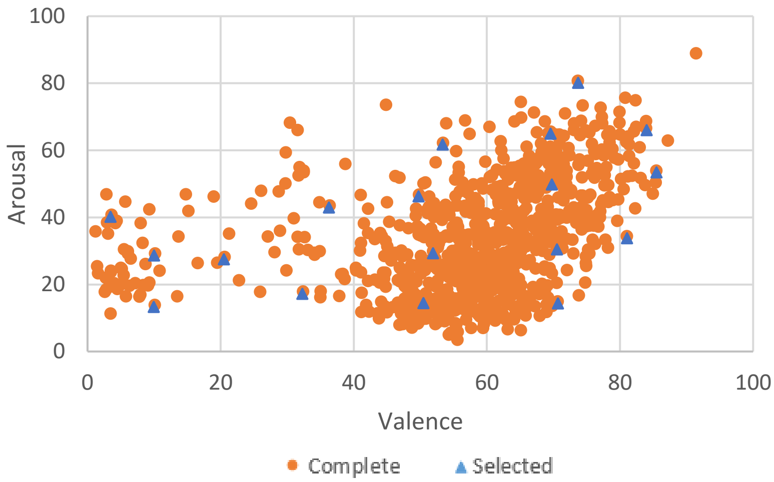
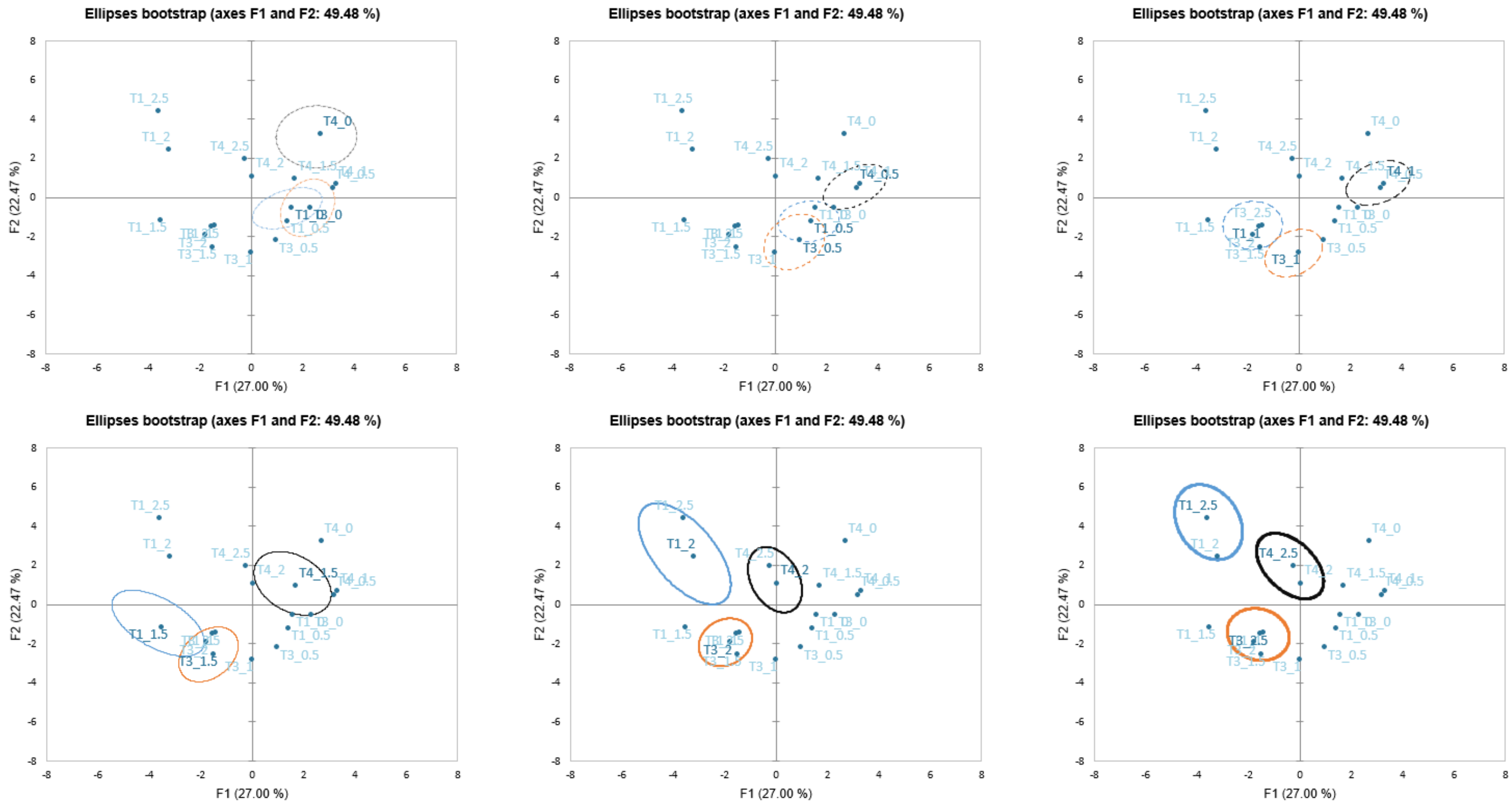


Figure 40. Distribution of the images from the FRIDa database in valence and arousal dimensions according to the validation study conducted by Foroni et al. (2013). Orange round markers represent the images from the complete database. Blue triangles represent the food images selected for our study.

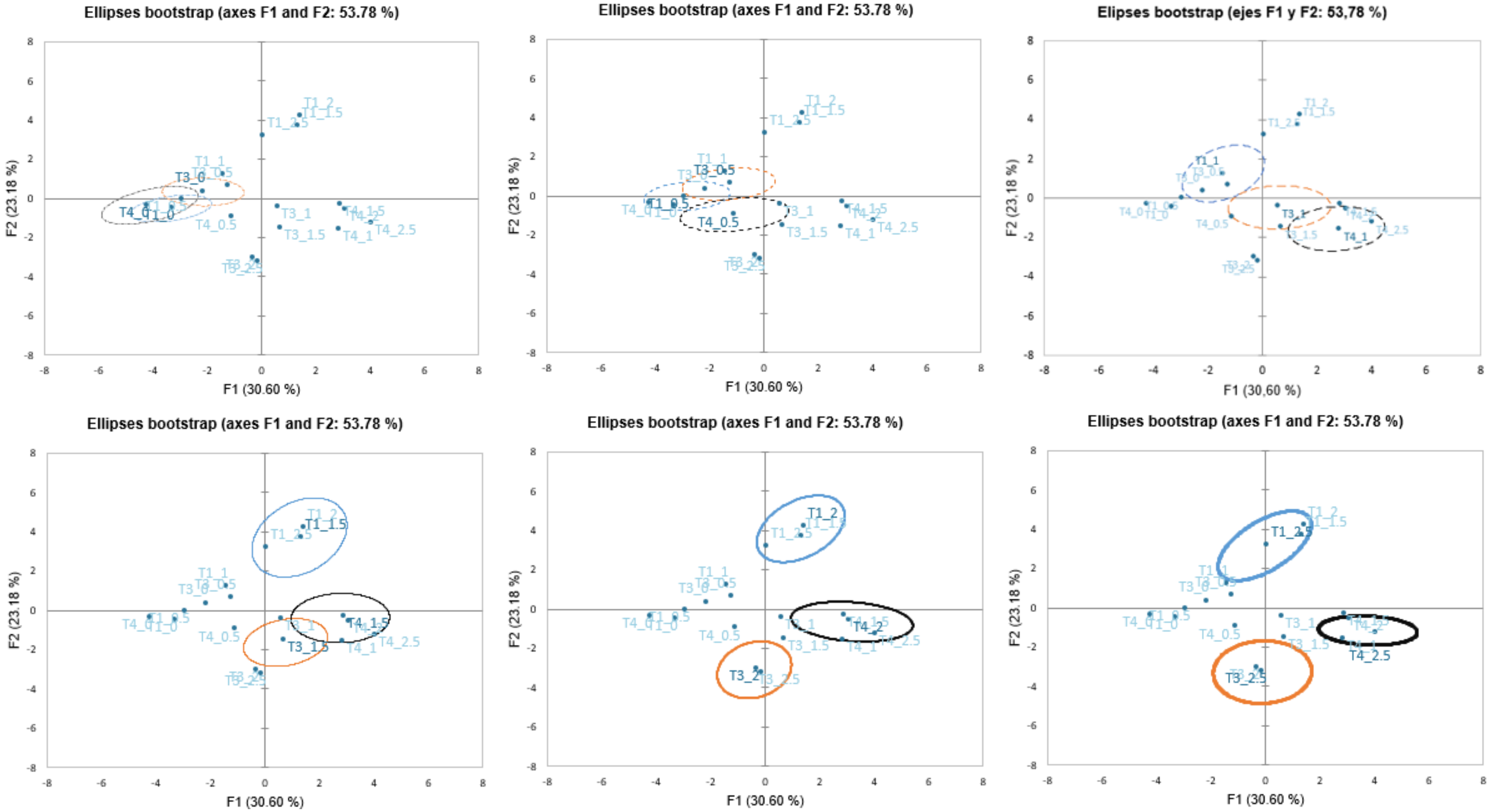
Table 16. Description of the food FRIDa images selected for our study and the valence and arousal average ratings obtained in the validation study conducted by Foroni et al. (2013).

Picture ID	Final Code	Valence	Arousal
pict_185	NF_025	71,0	15,0
pict_198	NF_038	85,2	56,6
pict_205	NF_045	79,8	34,5
pict_213	NF_053	70,4	28,4
pict_228	NF_068	36,8	44,0
pict_230	NF_070	51,9	15,7
pict_261	NF_101	51,9	29,9
pict_748	RF_006	19,1	29,9
pict_752	RF_010	4,0	46,1
pict_753	RF_011	10,2	29,2
pict_779	RF_037	10,4	13,8
pict_22	TF_022	73,9	81,5
pict_32	TF_032	69,0	65,5
pict_68	TF_068	53,0	60,5
pict_119	TF_119	83,9	67,8
pict_134	TF_134	31,7	16,8
pict_148	TF_148	67,5	50,4
pict_156	TF_156	51,1	46,8

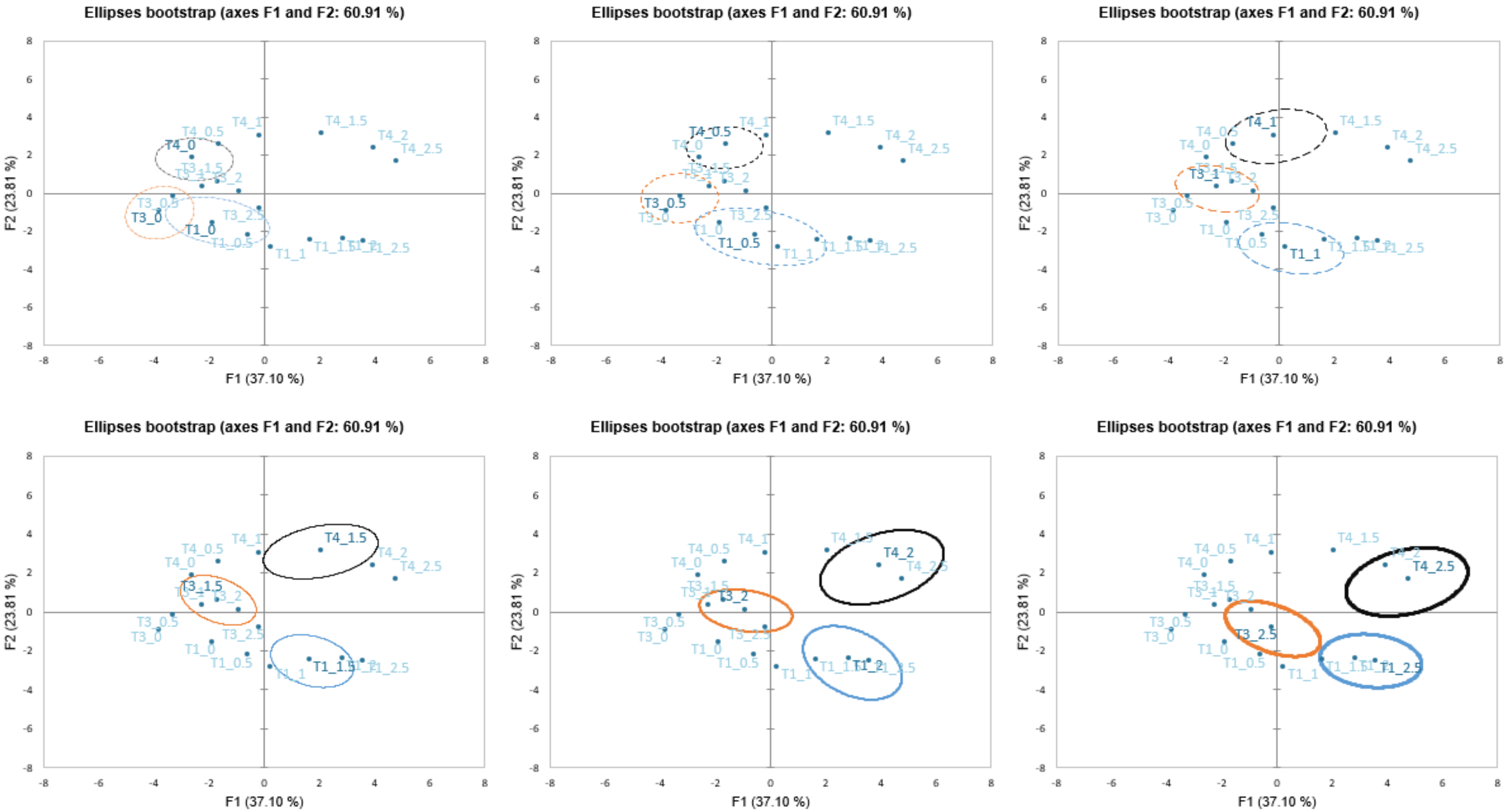
Appendix 3. PCA ellipses bootstrap obtained with physiological and behavioural (AUs) responses measured during the evaluation of liquid samples



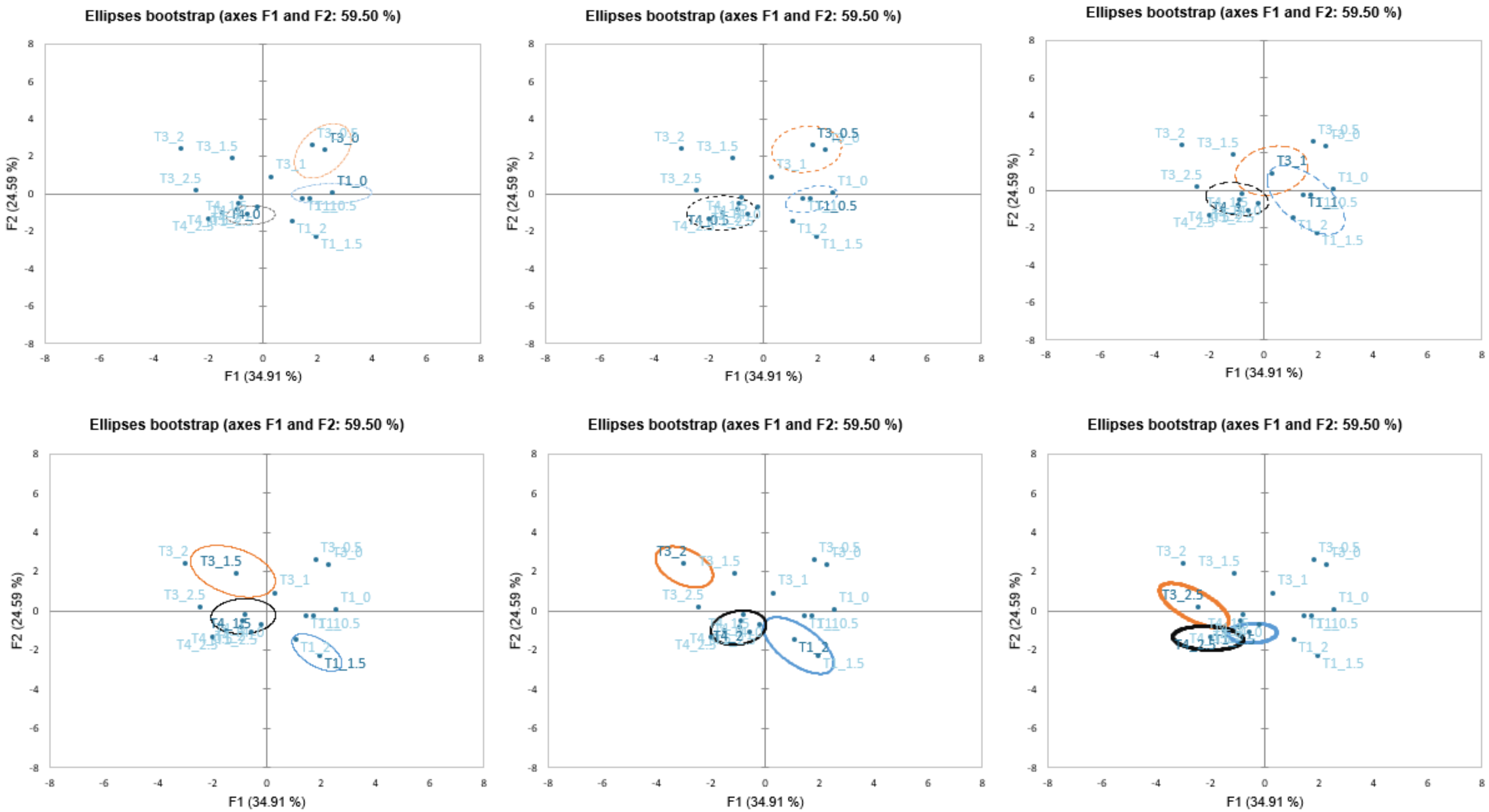
Appendix 3.1. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the observation of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.



Appendix 3.2. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

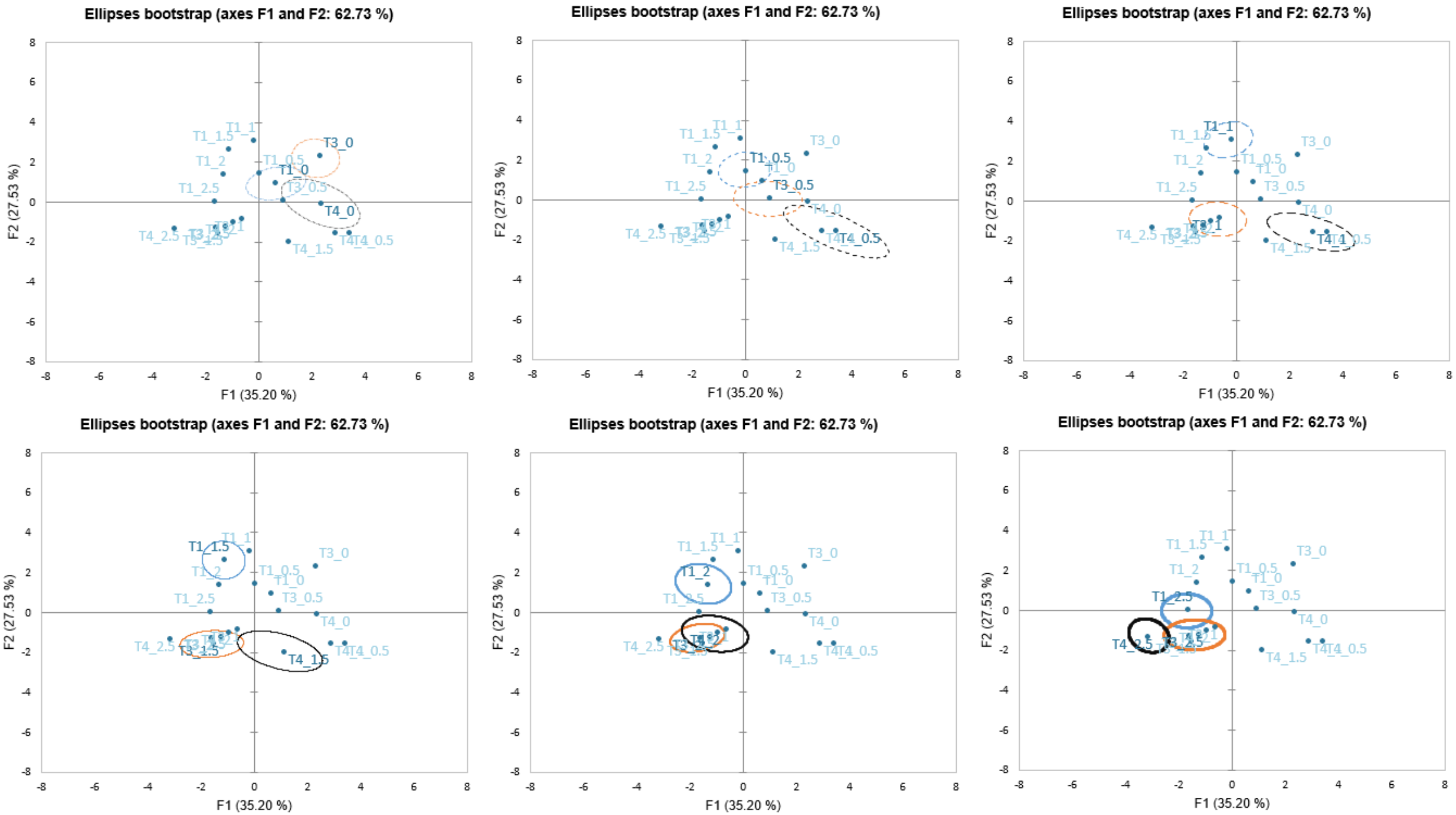


Appendix 3.3. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

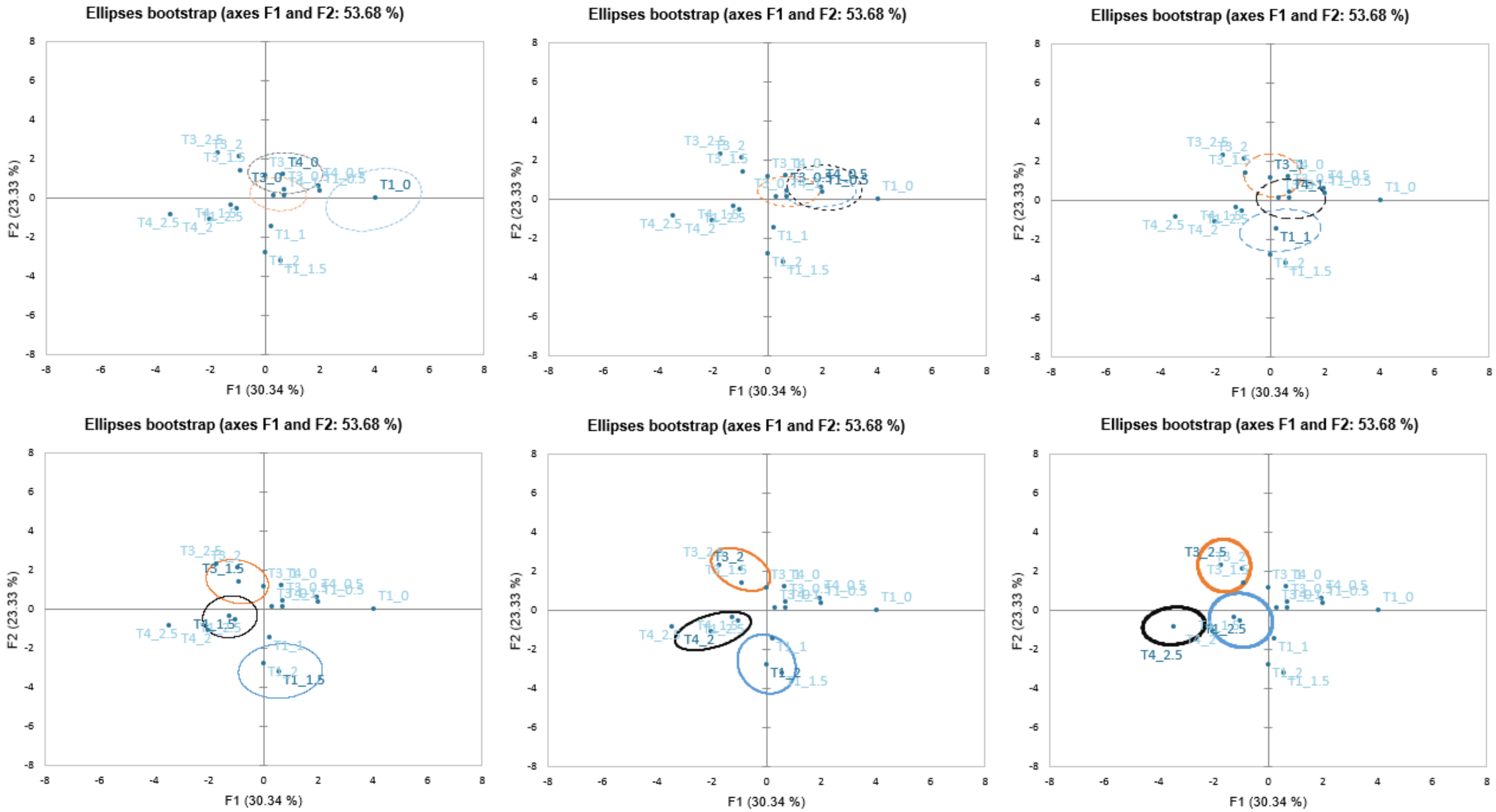


Appendix 3.4. Configurations obtained for liquid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the consumption of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

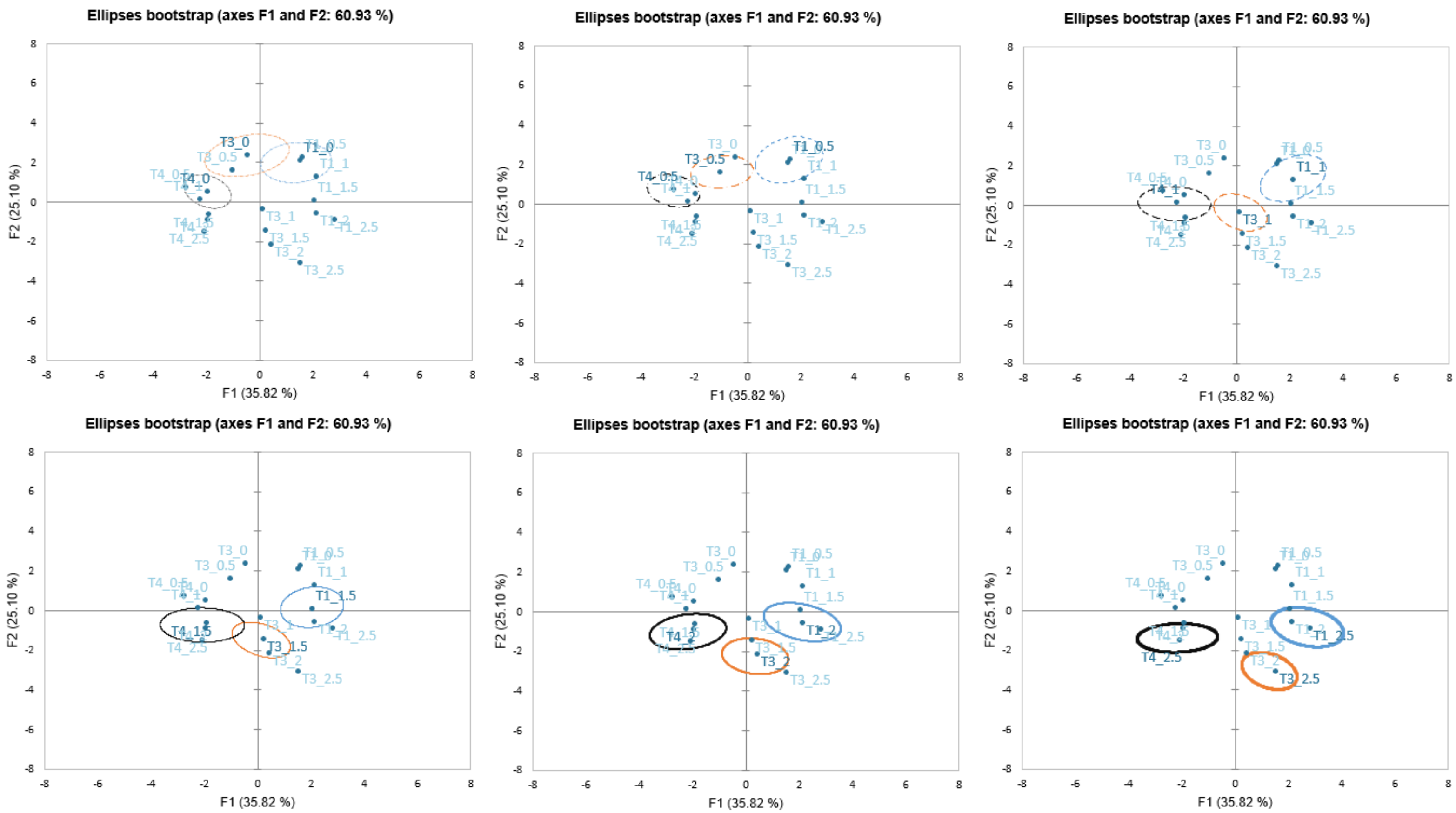
Appendix 4. PCA ellipses bootstrap obtained with physiological and behavioural (basic emotions) responses measured during the evaluation of liquid samples



Appendix 4.1. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the observation of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

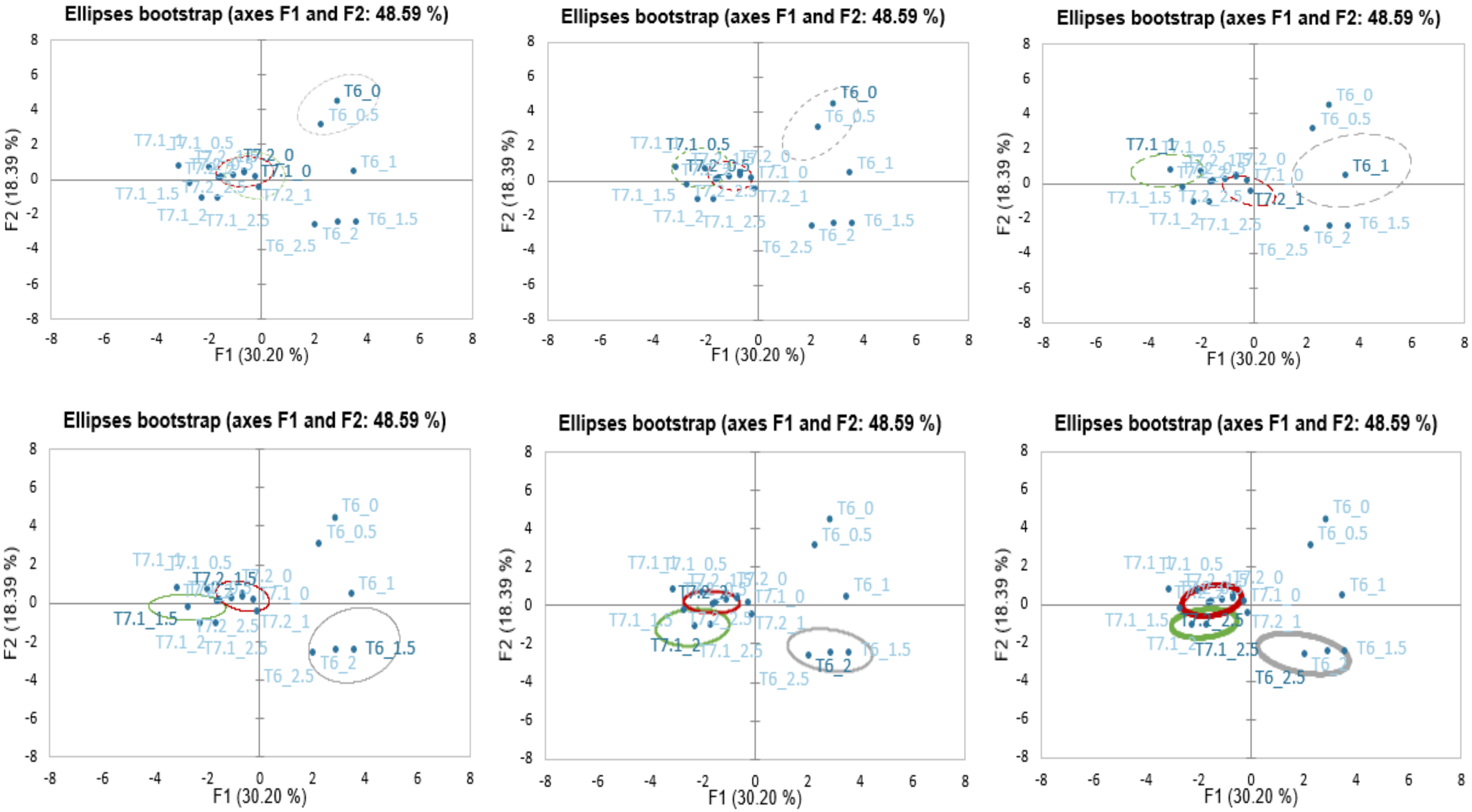


Appendix 4.2. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

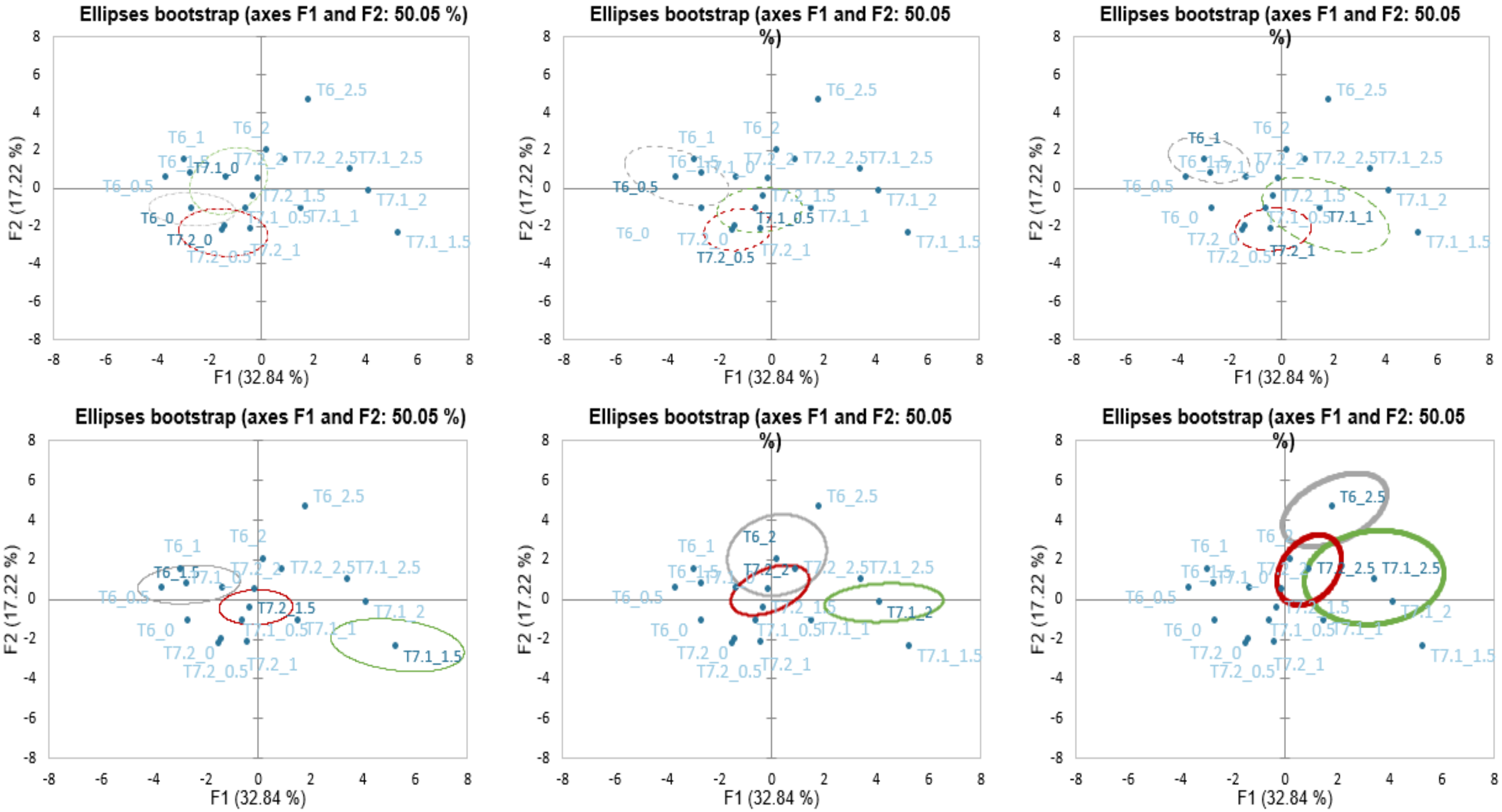


Appendix 4.3. Configurations obtained for liquid food products in a PCA conducted with basic emotion and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Products corresponded to the 1, 3, and 4 texture levels of IDDSI (IDDSI, 2019). T1: blue. T3: orange. T4: black. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

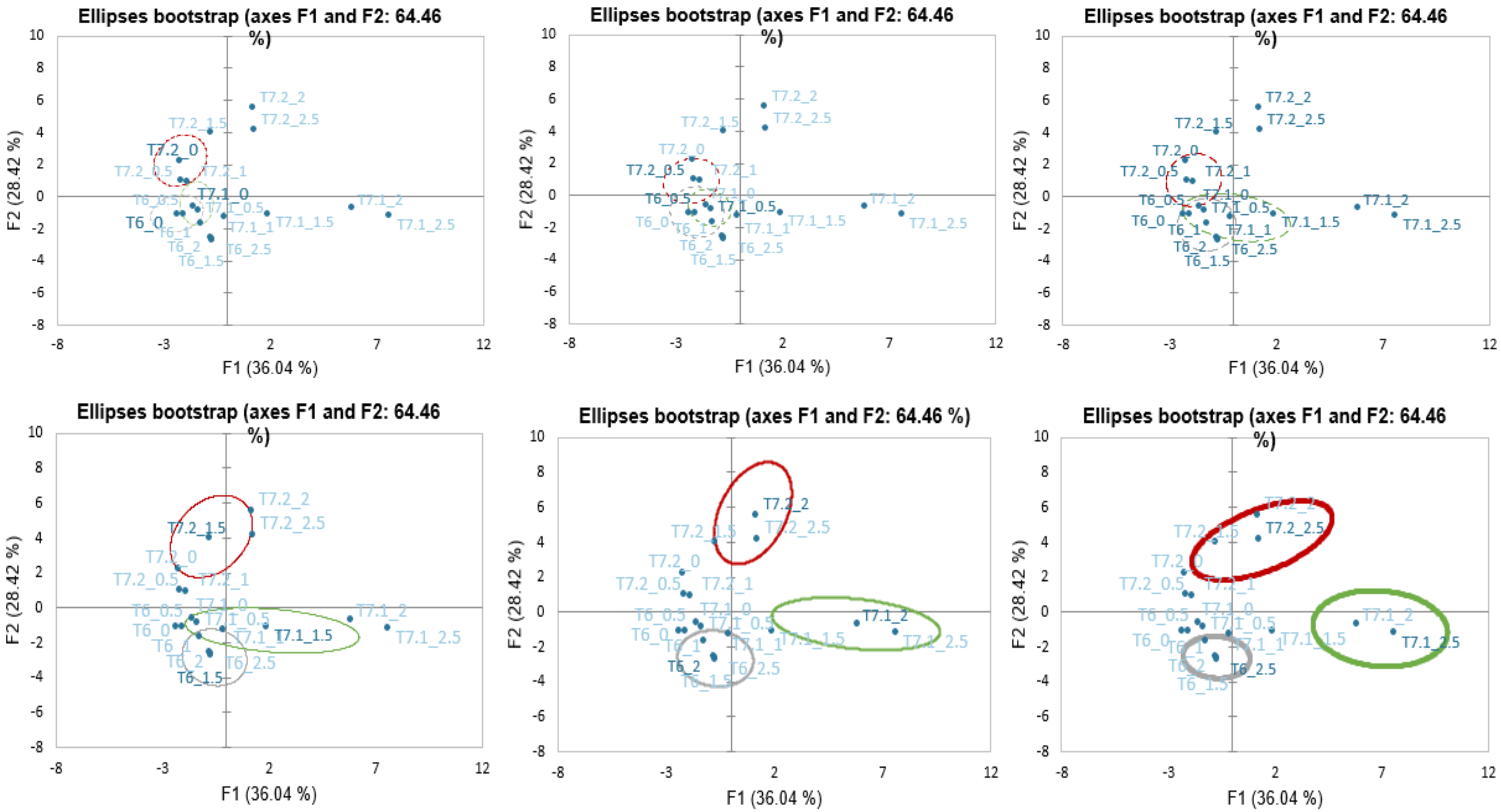
Appendix 5. PCA ellipses bootstrap obtained with physiological and behavioural (AUs) responses measured during the evaluation of solid samples



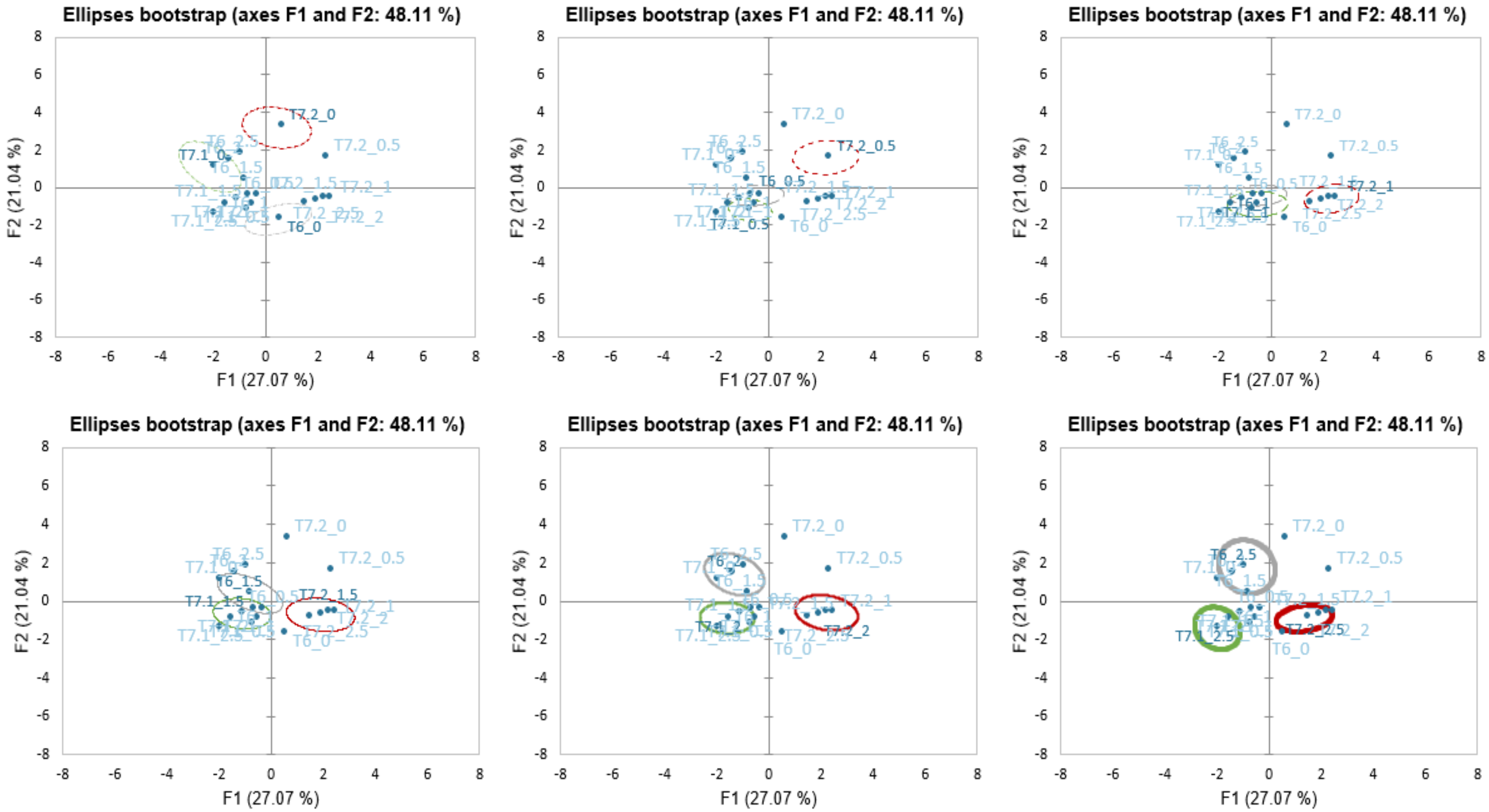
Appendix 5.1. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the observation of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.



Appendix 5.2. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

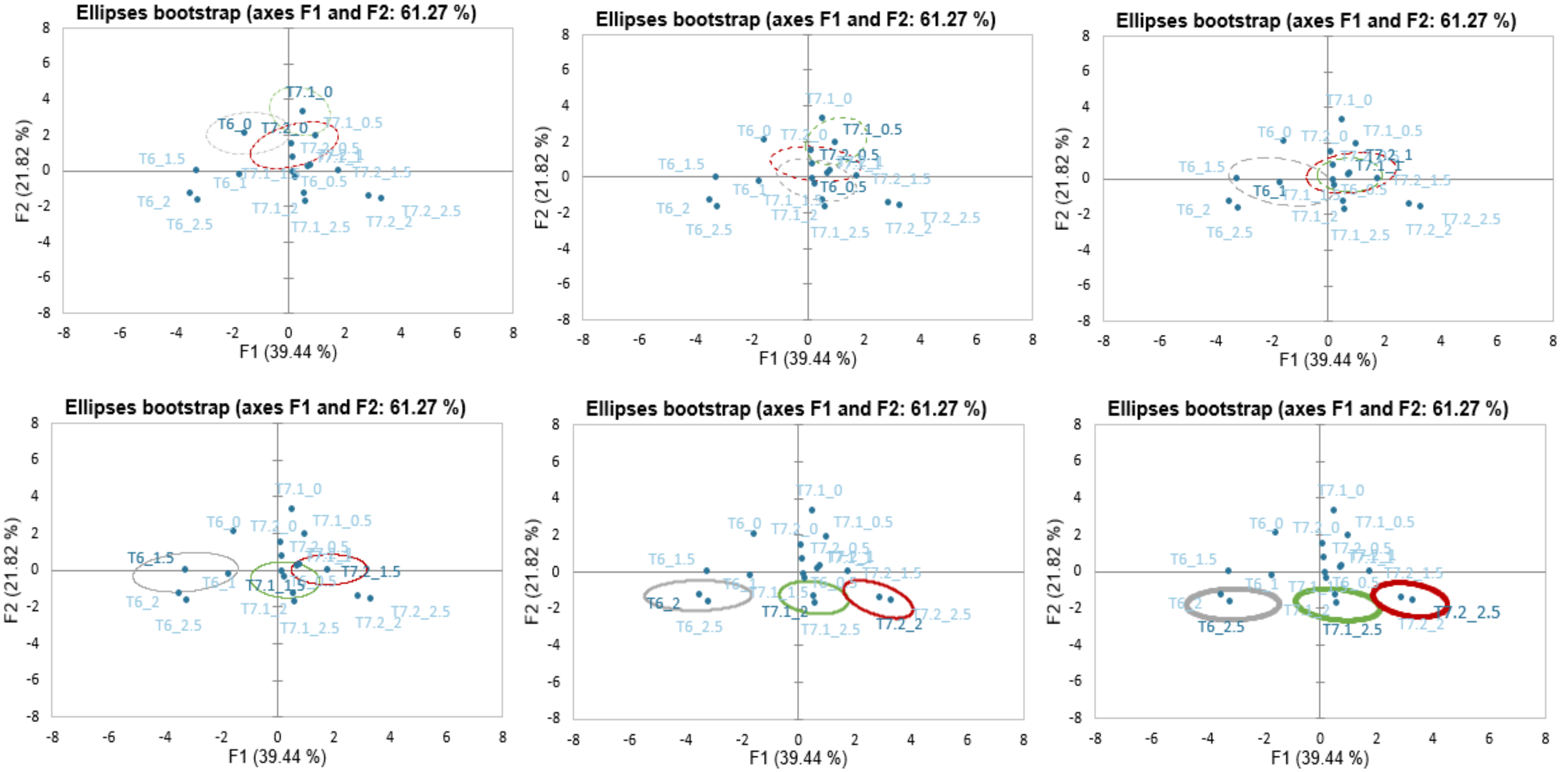


Appendix 5.3. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

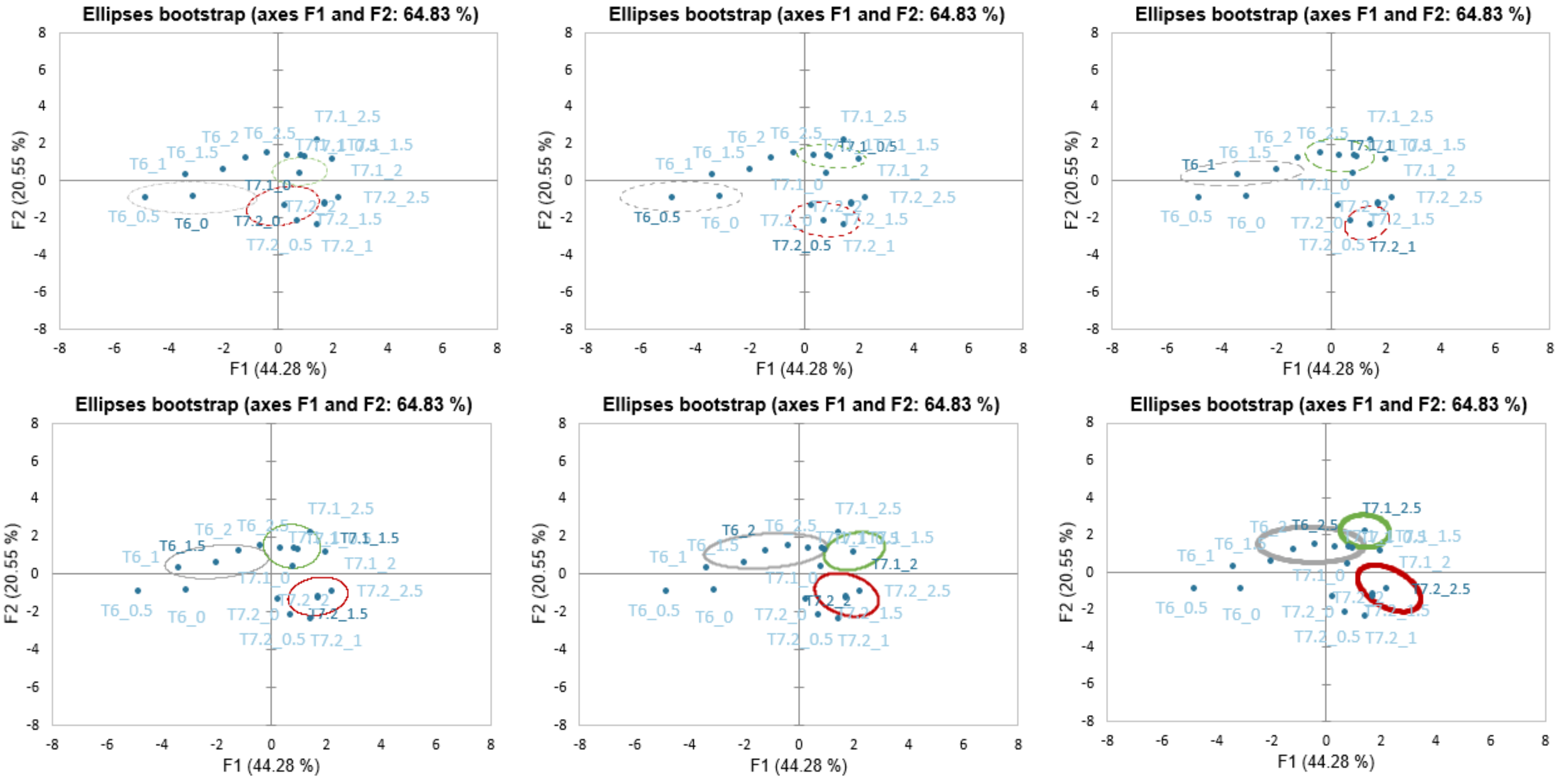


Appendix 5.4. Configurations obtained for solid food products in a PCA conducted with AUs and SCR data measured in schoolchildren (N=45) during the consumption of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

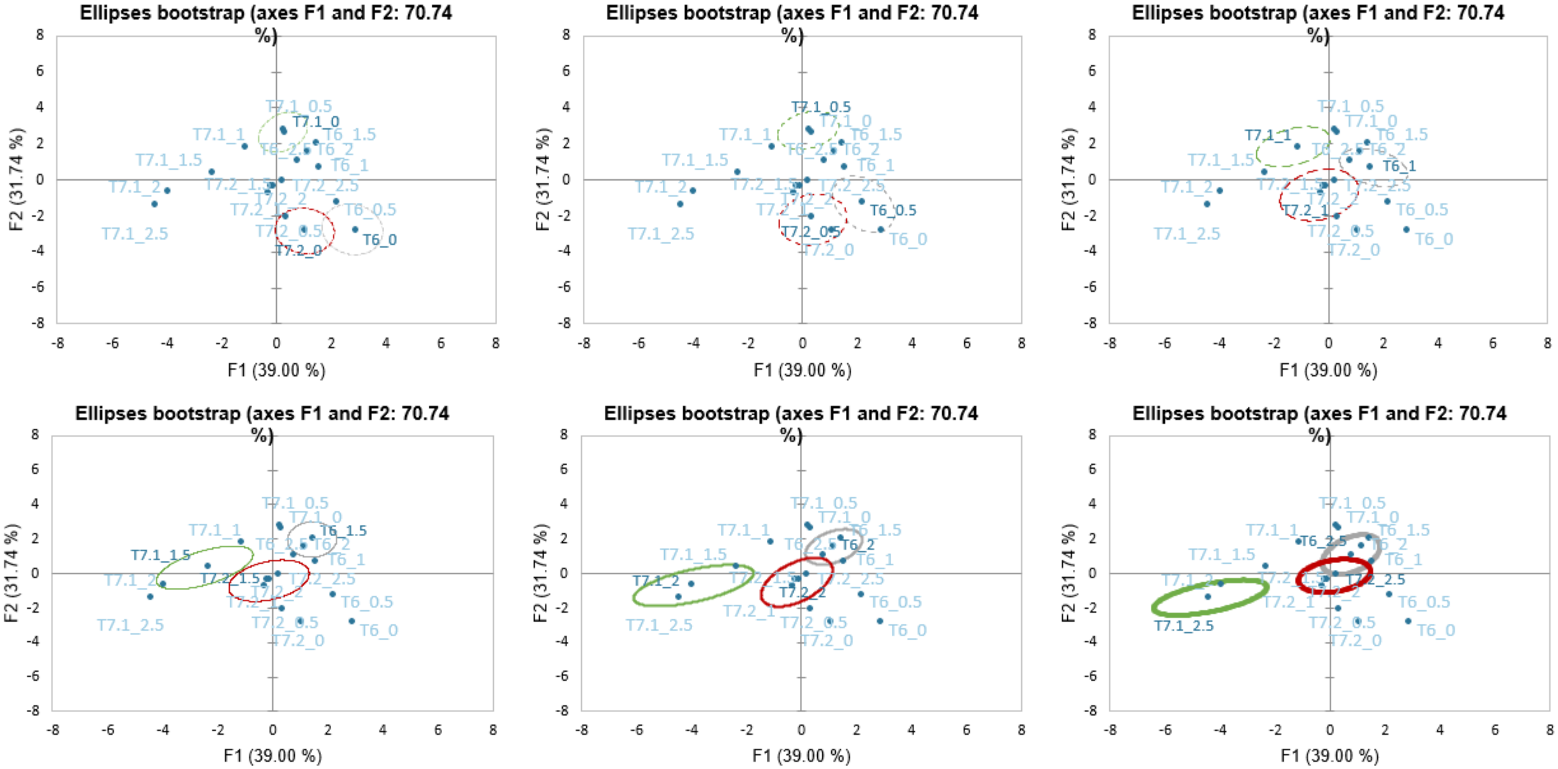
Appendix 6. PCA ellipses bootstrap obtained with physiological and behavioural (basic emotions) responses measured during the evaluation of solid samples



Appendix 6.1. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the observation of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.



Appendix 6.2. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the olfaction of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.



Appendix 6.3. Configurations obtained for solid food products in a PCA conducted with basic emotions and SCR data measured in schoolchildren (N=45) during the manipulation of the samples. Products corresponded to the 6, 7-Easy to chew (T7.1), and 7-Regular (T7.2) texture levels of IDDSI (IDDSI, 2019). T6: grey. T7.1: green. T7.2: red. Labels for the time-ranges: X_0: 0-500 ms. X_0.5: 500-1000 ms. X_1: 1000-1500 ms. X_1.5: 1500-2000 ms. X_2: 2000-2500 ms. X_2.5: 2500-3000 ms.

Appendix 7. Publications and contributions

Publications derived from the thesis work:

1. da Quinta N., Baranda A., Ríos Y., Llorente R., Martinez de Marañon I. Conscious and unconscious emotional response evoked by food appearance in children: a study based on automatic facial expression analysis and skin conductance response (2022). In: *Measuring Behavior 2022 Volume 2*. p. 139–48.

Other publications related to children's food behaviour, but not included in this thesis:

1. da Quinta N, Alvarez-Sabatel S, Martinez de Marañón I, Alfaro B. Children's acceptability profiles for biscuits with different fibre content. J Texture Stud [Internet]. 2021 Oct 30;53(1):41–51. Available from: https://doi.org/10.1111/jtxs.12642

Contributions to scientific conferences:

1. IV CONGRESO DE LA ASOCIACIÓN ESPAÑOLA DE PROFESIONALES DEL ANÁLISIS SENSORIAL (AEPAS) in 2022. Oral presentation:
   N. da Quinta, Y. Ríos, I. Martinez de Marañon. *Aplicabilidad de los emoji específicos del sector alimentario en estudios con población infantil. Comparativa con el método de referencia PrEmo.*

2. 12TH INTERNATIONAL CONFERENCE ON METHODS AND TECHNIQUES IN BEHAVIORAL RESEARCH (Measuring Behavior) in 2022. Oral presentation:
   N. da Quinta, A. Baranda, Y. Ríos, R. Llorente, I. Martinez de Marañon. *Conscious and unconscious emotional response evoked by food appearance in children: a study based on automatic facial expression analysis and skin conductance response.*

3. 14TH PANGBORN SENSORY SCIENCE SYMPOSIUM in 2021. Oral presentation:
   N. da Quinta, Y. Ríos, I. Martinez de Marañón. *Is product category or liking a deterrent for the application of food-specific emoji in evoked-product testing? A comparison with PrEmo among children.*

4. 9TH EUROPEAN CONFERENCE ON SENSORY AND CONSUMER RESEARCH (Eurosense) in 2020. Oral presentation:
   N. da Quinta, E. Santa Cruz, I. Martinez de Marañón, B. Alfaro. *What is behind a facial emoji? Children's understanding of facial emoji for a more accurate study of emotions.*

5. 13TH PANGBORN SENSORY SCIENCE SYMPOSIUM in 2019. Poster presentation:
   N. da Quinta, E. Santa Cruz, L. Rasines, A. Baranda, B. Alfaro. *Emotional eating behaviour in children: measuring facial expressions and visual attention.*

6. III CONGRESO DE LA ASOCIACIÓN ESPAÑOLA DE PROFESIONALES DEL ANÁLISIS SENSORIAL (AEPAS) in 2019. Oral presentation and award for one of the three best student communications:
   N. da Quinta, L. Rasines, E. Santa Cruz, A. Baranda, B. Alfaro. *Respuesta emocional en la aceptabilidad de alimentos en población infantil: expresión facial y atención visual.*

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