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EDULIA

WP2 Final report

Individual sensory sensitivity and development of food preferences in preadolescents

Photo: Nofima

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Executive summary
Individual sensory sensitivity and development of food preferences in preadolescents

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BACKGROUND

Children's food preferences are often inconsistent with dietary guidelines, promoting obesity. Our innate predispositions are maladjusted in today's abundant food environment, and naturally incline children towards easy energy obtainment and preference for sweet, salty and fatty foods. At the stage of preadolescence, the combination of unfavorable taste preference predispositions and a growing independence becomes critical for healthy food choices.

Determinants of healthy eating are multiple, including intrinsic and extrinsic product characteristics, and biological, physiological, psychological factors, situational and socio-cultural factors. Work Package 2 in the Edulia project has focused primarily on determinants related to the individual, namely taste sensitivity and psychological traits. Through studies conducted physically or remotely in Norwegian and Italian schools, WP2 has studied 10-13-year-old children's food perception and preferences with the aim to explore the role of individual sensory sensitivity and personality traits in preadolescents' food choice.

KEY FINDINGS

Across several studies based on different taste stimuli and measurement approaches, we mapped preadolescents' taste sensitivity in terms of detection threshold, recognition threshold, taste responsiveness and taste modality recognition. The results exhibit a good ability to identify sweet, sour, bitter and salty taste modalities in food samples, large inter-individual differences in taste responsiveness profiles, intra-individual differences in sensitivity to different bitter compounds (caffeine vs. quinine), and weak correlations between alternative sensitivity measures.

Further, we investigated the role of sensory sensitivity in the formation of food preferences, in relation to individual characteristics in emotional responses and personality traits. Model foods varying in intensity of warning (sourness and bitterness) and well-liked sensations (sweetness and saltiness) were specifically developed thus allowing the study of individual variation in responsiveness to taste and its relationship with liking and emotions. The results highlight that preadolescents have high preferences for fattiness and sweetness in foods and an aversion to bitterness and sourness. However, these main lines are modulated at individual level with fattiness sensitivity, taste responsiveness profile and psychological traits. Clusters of children were identified differing in responsiveness to innately liked (sweetness) and disliked (bitterness and sourness) tastes. These differences in taste responsiveness actively modulate the suppression effect of sweetness on warning sensations thus affecting liking for sour and bitter food. Differences in emotional patterns in response to food stimuli were identified which relate to differences in perception of and liking for food varying in intensity of warning and well-liked sensations.

From a methodological point of view, this research developed comprehensive and innovative sensitivity testing procedures for preadolescents with principles of gamification and remote testing capability.

CONCLUSIONS AND RECOMMENDATIONS

In summary, this work contributes to a better holistic understanding of taste and fattiness sensitivity in connection to food liking and personality traits in preadolescents. To our knowledge, this research is the first to investigate taste sensitivity for five basic tastes with two bitter compounds and across multiple taste sensitivity measures in preadolescents, and to explore the relationship between taste sensitivity and emotional responses in preadolescents.

We conclude that taste sensitivity is multi-faceted, with poor correlations between detection and responsiveness measures. By comparing caffeine to quinine in taste sensitivity testing of preadolescents, our findings show the importance of bitter stimulus selection in taste sensitivity and taste acceptance studies. We recommend the use of both compounds in future work interested in bitterness perception and individual differences, and stress that food developers should be aware of variations in bitterness perception across bitter compounds. Further, the results call for the development of different strategies specific to children's taste responsiveness profiles, to increase their acceptance for foods dominated by warning sensations of sourness and bitterness such as fruits and vegetables. Finally, this work highlights the importance of several dimensions contributing to food preferences in preadolescents including among other taste responsiveness, food familiarity, food neophobia, and food approach/food avoidance personal traits. Our data show the role of taste responsiveness in food preferences expression and its interrelationships with other factors. In particular, sucrose addition is an efficient suppressor of sourness and bitterness in subjects highly sensitive to sweetness and poorly sensitive to sourness and bitterness, but not in subjects with opposite responsiveness traits. These results are relevant to nutritionists and food developers aiming at tackling bitterness and sourness rejection in children.

The usage of gamified procedures to engage the children and the usage of remote sensory testing as an alternative approach for sensory data collection in preadolescents are suggested for further study. Further research may investigate if the associations uncovered between taste sensitivity and food acceptance are stable across different model food samples, basic tastes and chemical compounds, and cultures.

2 Introduction

2.1 Scientific background

Children's food preferences are often inconsistent with dietary guidelines and a healthy lifestyle, promoting obesity (Spinelli et al., 2021). Predispositions developed in hostile food environments are maladjusted in today's abundant food environment, and naturally incline children towards easy energy obtainment and preference for sweet, salty and fatty foods (Birch, 1999). This is especially true at the stage of preadolescence (9 to 13 years) when the child develops their own decision-making with regard to food choices, and is more inspired by the (hedonic) choices of peers than by the (reasonable) choices of adults (Havdal et al., 2021). The combination of unfavourable liking predispositions and a growing independence make this a critical period for healthy food choices.

Determinants of healthy eating are multiple, from the perception of intrinsic product characteristics, biological and physiological factors, psychological factors, situational factors, and socio-cultural factors to expectations from extrinsic product characteristics (Köster, 2009). Work Package 2 (WP2) focuses primarily on determinants related to the individual: taste sensitivity and psychological traits.

2.1.1 Taste sensitivity

Taste sensitivity may be defined as an individual's ability to respond to taste stimuli. This can be decomposed into four independent measures (Webb et al., 2015):

- The **detection threshold (DT)** is the lowest concentration at which a taste compound can be detected. This is typically measured in water solutions of increasing taste concentrations.
- The **recognition threshold (RT)** is the lowest concentration at which a taste stimulus can be correctly named for its quality (i.e., sweet, sour, salty, bitter, umami). This is typically measured in water solutions of increasing taste concentrations.
- The **taste responsiveness** or suprathreshold intensity perception is the measure of taste intensity perception above the threshold levels. This is typically measured in water solutions or in model food samples of increasing taste concentrations. In particular, **PROP bitterness intensity** is the specific measure of taste intensity perception of 6-n-Propylthiouracil (PROP) and is considered a reliable index of oral sensitivity. It is typically measured on paper discs/strips or in water solutions.
- **Taste modality recognition** measures the subjects' ability to identify the different taste qualities (i.e., sweet, sour, salty, bitter, umami) present in taste stimuli, e.g., in food samples.

Sensitivity to the basic tastes show considerable individual variability, influencing food acceptability and intake (Nasser, 2001). However, this has not been thoroughly studied in children: no previous study has investigated taste detection, taste recognition and taste responsiveness across the five basic tastes in a preadolescent population. Further, fat taste perception is poorly understood, and the scientific community is still debating the definition of fattiness as a basic taste (Liu et al., 2016). However, fatty acid sensitivity has been linked with energy and fat intakes and Body Mass Index (BMI) (Stewart et al., 2010). There is a need for better understanding fat taste perception and its association with food consumption also in children.

2.1.2 Psychological traits

Individual differences in psycho-attitudinal traits affect food preferences and intake, and were shown to affect sensory responses and liking in adults (Laureati et al., 2018; Spinelli et al., 2018).

- **Food neophobia** (the reluctance to try novel food) is a well-known trait in children affecting food preferences and was shown to lead to decreased intake of fruits and vegetables in 12-13-y.o. children (Guzek et al., 2018).
- **Sensation seeking** is a further notable predictor for food choice among personality traits related to foods. In general, it is defined as an individual's increased willingness to take risks to seek new or intense stimuli (Alley & Potter, 2011). Individuals high in sensation seeking require a lot of stimulation to reach the appropriate level of arousal and they are more open to new food experiences, following they tend to be less food neophobic (Alley & Potter, 2011; Pliner & Melo, 1997). It may be hypothesized that children high in sensation seeking may also seek new or more extreme experiences related to food, but research exploring the role of sensation seeking in children's food preferences appears to be a neglected topic.
- The **curiosity trait** can be generally defined as the recognition, pursuit, and desire to explore novel, uncertain, complex, and ambiguous events (Kashdan et al., 2018). There have only been a few studies that examined the role of curiosity in sensory science and consumer behaviour, however, this trait was suggested to be a key predictor of willingness to try novel food (Stone, FitzGibbon, Millan, & Murayama, 2021). A study investigating underlying stated reasons for food acceptance and rejection in 10-13-y.o. children found that curiosity was stated as the most important reason in girls and the second most important reason in boys (after taste) to accept unfamiliar foods (Sick, Højer, & Olsen, 2019).
- It was found that **reward sensitivity** was positively associated with food approach, whereas **punishment sensitivity** was positively associated with food avoidance in preschool children (Vandeweghe et al. 2016). In particular, 14-16-y.o. girls with higher sensitivity to reward were found to have a higher daily intake of snacks and sugar sweetened beverages (De Cock et al., 2015).

Investigating the role of psychological traits in food-evoked emotions is important to better understand consumer's food choice. Food-evoked emotions and liking are closely related in the sense that positive emotions are related to liking, while negative emotions are related to dislike (Spinelli, Monteleone, Ares, & Jaeger, 2019). Moreover, sensory properties of basic taste stimuli (Dubovski et al., 2017) and foods (Jaeger, Spinelli, Ares, & Monteleone, 2018; Spinelli & Jaeger, 2019) were shown to evoke emotions, and responsiveness to PROP was shown to influence emotional responses (Dubovski, Ert, & Niv, 2017; Macht & Mueller, 2007).

2.2 Objectives of Work Package 2

Work Package 2 (WP2) aims to explore the role of individual sensory sensitivity to basic tastes and fattiness in preadolescents' food choices, and to understand the effects of sensory sensitivity and personality traits on emotional responses and consequences in food wanting and food liking. By providing a better understanding of individual diversity in food perception and emotional responses, WP2 contributes to Edulia with key insights for developing and targeting healthier food choices at 9-13-year-old children.

To achieve our objective, a subgoal of the WP has been to develop data collection methods to investigate preadolescents' taste sensitivity towards the five basic tastes and fattiness. Due to the

COVID-19 pandemic, both classical and remote-testing approaches have been developed. This constitutes a valuable methodological contribution to the scientific community.

2.3 Work Package 2 organisation

2.3.1 WP2 Tasks

The work package has been organised in two tasks decomposing the overall objective of the project in separate activities: T2.1 was focused on taste sensitivity and T2.2 established the role of sensory sensitivity in the formation of food preferences. These tasks are further described below. The WP involved two partners: Nofima and the University of Florence (UNIFI). Two Early-Stage Researcher (ESR) projects were anchored in WP2: Ervina (ESR2) investigated the importance of sensory sensitivity for food perception among preadolescent children, and Julia Sick (ESR3) investigated the role of emotions, personality traits and sensory sensitivity in food preferences in preadolescents (Table 1).

Table 1. WP2 organisation in two tasks

Task	Objective	Partners	Leadership	ESRs
2.1 Sensory sensitivity of basic taste and fattiness	To map sensory sensitivity of the basic tastes and fattiness	Nofima, UNIFI	V.L. Almli, Nofima[1]	ESR2
2..2 The role of sensory sensitivity in formation of children's food choice	To uncover relationships between sensory sensitivity, hedonic preferences, food neophobia, product emotions, food choice and BMI	Nofima, UNIFI	C. Dinnella, UNIFI[2]	ESR2, ESR3

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Within the Edulia project, WP2 interacted with WP3 Methods development on the issue of food-elicited emotion measurement in preadolescents. Figure 1 shows the global study design in WP2 and highlights the collaboration between ESR2 and ESR3 projects.

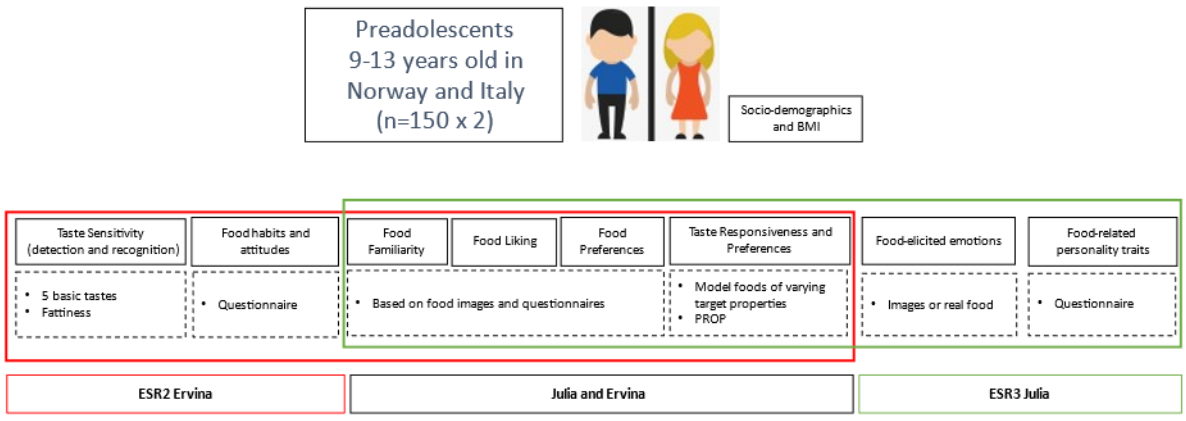

Figure 1. Global study design in WP2 allying data collection in two ESR projects

3 Task 2.1 Sensory sensitivity of basic taste and fattiness

3.1 Background and objectives

T2.1 focused on mapping individual taste sensitivity in preadolescents for the five basic tastes and fattiness. Recent European research has described differences in taste sensitivity in 7- to 11-year-old children from eight European countries, with a focus on detection threshold for four taste qualities: sweet, bitter, salty and umami (Jilani et al., 2022). We here aimed to study different aspects of taste sensitivity in preadolescent children in a standardised way across the five basic tastes, as well as sensitivity for fattiness.

3.2 Methodology

3.2.1 Overview of WP2 studies

The studies conducted in WP2 were designed across tasks T2.1 and T2.2 and are presented here.

Five experimental studies were conducted in Norway and Italy with children 10-13 years old, investigating different sensitivity, hedonic and emotional measures for a variation of taste stimuli (Table 2). Over 540 preadolescents and 69 parents participated in the studies. All testing with children was conducted at school during school time in collaboration with the teachers. Real food samples, model food samples and single taste compounds dissolved in water solutions, were employed to measure taste sensitivity in children. In addition, children's taste sensitivity was measured by several approaches, namely: taste modality recognition, detection and recognition threshold, and perceived taste intensity. Data from the children's parents regarding their child's eating behaviour and food consumption frequencies were also collected using an online questionnaire.

Table 2. Overview of WP2 studies *(Abbreviations:* y.o.: years old; CATA: Check-all-that-apply; DT: Detection Threshold; RT: Recognition threshold; PROP: 6-n-Propylthiouracil; LMS: Labeled Magnitude Scale; LAM: Labeled Affective Magnitude Scale)

Study # (location)	Subjects	Samples	Sensitivity measures	Hedonic and behavioural measures
1 (Norway)	N=98, 53% boys, 10-11 y.o.	19 unfamiliar foods from five categories (dairy, meat based, cereals, fruit and vegetables, and sweets)	Basic taste sensations perceived in a CATA question offering four alternatives: sweet, sour, salty and bitter	Liking measured on a seven-point pictorial hedonic scale
2 (Norway)	N=106, 46% boys, 11 y.o.	• Water solutions in 5 concentrations of saccharose (sweet), citric acid (sour), sodium chloride (salty), monosodium glutamate (umami), caffeine and quinine (both bitter) • Milk samples with 0.5% (low), 1% (medium), and 1.5% (high) fat content	• Basic tastes DT and RT; Responsiveness to basic tastes; PROP responsiveness • Fat sensitivity: fattiest milk identification in paired comparisons	• Liking for basic tastes (water solutions) on a seven-point pictorial hedonic scale • Stated liking for 30 food items representing the five basic tastes and fattiness on a seven-point pictorial hedonic scale
3 (Norway)	N=69*, 47% boys, 11 y.o. *Participants from study 3 are a subset from study 2	Water solutions in 5 concentrations of saccharose (sweet), citric acid (sour), sodium chloride (salty), monosodium glutamate (umami), caffeine and quinine (both bitter)	• Basic tastes DT	• Child Eating Behaviour Questionnaire (CEBQ) • Food Propensity Questionnaire (FPQ) filled in by a parent
4 (Norway)	N=148, 48% boys, 12 y.o.	Model foods: Grapefruit juice with sucrose added and vegetable broth with sodium chloride added at four concentrations	• Intensity perception in model foods (LMS) • PROP responsiveness (paper disc)	• Stated liking of 28 food items on a seven-point scale and emotional responses (CATA Emoji Pair Questionnaire) • Stated food choice in 19 food pairs representing sourness and bitterness variations • Liking (LAM) and emotional responses to model foods (Emoji Pair rating scale) • Personality traits
5 (Italy)	N=123, 58% boys, 11-13 y.o.	Model foods: Grapefruit juice with added sucrose at four concentrations	• Intensity perception in model foods (LMS) • PROP responsiveness (paper disc)	• Stated liking of 28 food items on a seven-point scale) and emotional responses (CATA Emoji Pair Questionnaire) • Stated food choice in 19 food pairs representing sourness and bitterness variations • Liking (LAM) and emotional responses to model foods (Emoji Pair rating scale) • Personality traits

3.2.2 Method development, gamification and remote testing

An important activity in T2.1 was to develop data collection methods to investigate preadolescents' taste sensitivity towards the five basic tastes and fattiness. Testing approaches were developed that ensured suitability to the children's cognitive development level, task autonomy, and engagement through principles of gamification.

To ensure suitability of the task for the age group, sensitivity testing procedures for DT and RT were based upon the staircase procedure described by Jilani et al. (2019) for children 7 years and older. The choice of tastants was however expanded to include all five basic tastes, with two chemicals representing bitterness in water solutions: caffeine and quinine (Table 3). Choice and concentration levels of tastants were based upon previous literature, pretesting and pilot testing. We refer to Ervina et al. (2020a) for further information.

Table 3. Concentration levels of taste compounds for detection and recognition thresholds in studies 2 and 3

Taste quality	Taste compound	Level 1 (g/l)	Level 2 (g/l)	Level 3 (g/l)	Level 4 (g/l)	Level 5 (g/l)
Sweet	Sucrose	3.0	6.0	9.0	12.0	16.0
Sour	Citric acid	0.05	0.1	0.16	0.2	0.25
Salty	Sodium chloride	0.2	0.4	0.8	1.2	1.6
Umami	Monosodium glutamate	0.1	0.3	0.6	1.2	1.5
Bitter	Caffeine	0.05	0.1	0.15	0.2	0.27
Bitter	Quinine	0.0014	0.0017	0.0023	0.0038	0.006

Autonomy in testing was ensured to avoid interviewer bias, to avoid discomfort as may occur in one-to-one interviews for the shyest participants, and to allow simultaneous testing of whole school classes. The data collection was conducted on the children's school tablets or PCs. Short on-screen instructions and simple question wordings were developed and adjusted from pilot testing.

Creating engagement in the study through gamification ensures higher participation, fewer dropouts, better participant experience and better data quality through better focus on the tasks (Adamou, 2018; Laureati & Pagliarini, 2018). In Norway, a "Taste detective" game context was created involving an illustrative character and a series of "missions" and "bonus mission" to be solved by the participants. In Italy, an Edulia character was introduced to accompany the children in their tasks (Figure 2).

Figure 2. ***Left*****: Screenshot of The Taste Detective Game in the online platform (translated from Norwegian).** ***Right*****: Screenshot of the character "Edulia – the supertaster" in the online platform (Italian study)**

As data collection for study 4 was conducted in 2020 under the pandemic, schools could not be visited. A remote testing procedure was developed where the test samples were prepared, packed individually for each participant, and delivered to the schools in the morning of the testing days (Figure 3). Then, during the sessions the experimenters communicated instructions to the participants through video call on the classroom's smart board. Importantly, preparation meetings were conducted beforehand with the schoolteachers and assistants to ensure that everyone was informed on specific tasks to be done in the classrooms, such as distributing the testing packs to the children, serving rinsing water, or helping the children to tidy away taste samples. By interacting though video call, the experimenters' "visit" was less invasive than a physical visit, possibly allowing for less excitement and disruption in the children's behaviour and concentration.

Figure 3. Prepacked samples of model foods (grapefruit juice and vegetable broth) for a participant in study 4, for delivery to the children's schools (Norway)

The study in Italy was postponed until spring 2022, allowing for physical sample preparation and testing in schools (Figure 4).

Figure 4. Prepared samples of model foods (grapefruit juice) for a participant in study 5 (Italy).

3.3 Main results

Results from T2.1 show that children 10-11 years old were able to identify the basic tastes (sweet, sour, bitter and salty; umami omitted from the study) of unfamiliar food samples with good congruency to a trained panel. The use of unfamiliar foods ensured that their identification ability relied on taste perception, not on prior knowledge. However, children's taste identification ability was lowered when a combination of dominant basic tastes occurs (Ervina et al., 2020a). These results indicate that a training session to define sweet, sour, bitter and salty could be superfluous when conducting sensory testing with preadolescents.

The different taste sensitivity methods were weakly but significantly correlated to one another, except PROP responsiveness and RT. These weak correlations indicate that different sensitivity measurements may capture different aspects of taste perception. DT and taste responsiveness better differentiated children's taste sensitivity than RT and PROP. Further, boys showed to have a lower taste sensitivity than girls for sweet and bitter tastes in terms of detection threshold. Interestingly, the two bitter compounds of caffeine and quinine only showed moderate correlations in sensitivity, and were perceived differently in terms of responsiveness and liking (Ervina et al., 2020b).

In terms of taste responsiveness to model foods, four segments representing individual differences in taste responsiveness were formed: High Responsive to Bitter and Sour (24%), Low Responsive to Sweet (23%), Low Responsive to All Basic Tastes (34%), and High Responsive to All Basic Tastes (19%). The suppression effect of sweetness on bitterness and sourness intensity was related to the different taste responsiveness profiles of the four segments. In fact, sucrose addition suppressed sourness and bitterness perception only in subjects with high responsiveness to sweetness and low responsiveness to sourness and bitterness. On the other hand, a low responsiveness to sweetness or a high responsiveness to sourness and bitterness strongly lowered the sucrose suppression to bitterness and sourness intensity (Ervina et al., 2021b).

From a methodological perspective, sensory testing of preadolescents in autonomy, in a gamified approach, and in remote testing conditions was successful.

3.4 Conclusion

Through different studies and based on different taste stimuli and measurement approaches, T2.1 mapped preadolescents' taste sensitivity in terms of detection threshold, recognition threshold, taste responsiveness and taste modality recognition. The results exhibit a good ability to identify sweet, sour, bitter and salty taste modalities in food samples, large inter-individual differences in taste responsiveness profiles, intra-individual differences in sensitivity to different bitter compounds (caffeine vs. quinine), and weak correlations between alternative sensitivity measures. Sucrose addition is an efficient suppressor of sourness and bitterness in subjects highly sensitive to sweetness and poorly sensitive to sourness and bitterness, but not in subjects with opposite responsiveness traits. These results are relevant to nutritionists and food developers aiming at tackling bitterness and sourness rejection in children.

Future research may investigate cross-cultural variations on taste modality recognition, taste sensitivity thresholds and taste responsiveness profiles in preadolescent children. Moreover, research is needed to better understand which bitter compound(s) should be used in different sensory studies. While caffeine and PROP are largely used as bitterness sensitivity markers, these compounds may not be representative of all types of bitterness represented in food samples.

3.5 Further reading

Ervina (2021). Taste sensitivity and food liking in preadolescent children. PhD thesis. Faculty of Chemistry, Biotechnology and Food Science, University of Life Sciences, Ås, Norway

Ervina, E., Berget, I., Nilsen, A. and Almli, V.L. (2020a), The ability of 10-11-year-old children to identify basic tastes and their liking towards unfamiliar foods. *Food Quality and Preference, 83*, 103929. https://doi.org/10.1016/j.foodqual.2020.103929

Ervina, E., I. Berget, and V. L. Almli (2020b), Investigating the Relationships between Basic Tastes Sensitivities, Fattiness Sensitivity, and Food Liking in 11-Year-Old Children. *Foods, 9*(9), 1315. https://doi.org/10.3390/foods9091315

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Ervina, E., Almli, V. L., Berget, I., Spinelli, S., Sick, J., & Dinnella, C. (2021b). Does responsiveness to basic tastes influence preadolescents' food liking? Investigating taste responsiveness segment on bitter-sour-sweet and salty-umami model food samples. *Nutrients*, *13*(8), 2721.

4 Task 2.2 The role of sensory sensitivity in formation of children's food choice

4.1 Background and objectives

Taste is considered a key determinant in food preferences and intake. Innately disliked sensations such as bitterness and sourness represent a sensory barrier for preference and intake of fruit and vegetables in adolescents (Appleton et al.,2019), and liking of taste and texture were the best predictors of children vegetable overall liking (Estay et al., 2019). Individual differences in responsiveness to chemosensory stimuli and in personality traits affect both sensory perception and liking of food in adults (De Toffoli et al., 2019). Also, differences in food-elicited emotions could play an important role for a deeper understanding of individual factors shaping food choice and intake (Spinelli and Jager 2021). The interplay among these different factors is currently under-investigated in preadolescents. T2.2 aimed at investigating the relationships between sensory responsiveness, psychological traits and emotional responses to food in the formation of food preferences in preadolescents. Anthropometric measures (BMI) and demographic factors (age and gender) were also considered.

4.2 Methodology

The studies conducted in WP2 were designed across tasks T2.1 and T2.2. Thus, T2.2 is based on studies 1-5 presented in Table 2 above. In addition to measuring the children's taste sensitivity, their liking, sensory and emotional responses to model food samples were measured. Sensory responses to single taste compounds dissolved in water solutions were measured as well. Additionally, stated liking for foods representing different variations in basic taste modalities was expressed on hedonic scales and in paired comparisons. Data from the children's parents regarding their child's eating behaviour and food propensities were also collected using an online questionnaire (study 3). Food propensity questionnaires (FPQs) provide information for long term intakes and food group consumption.

Children were clustered based on their sensory responses to basic tastes and food models. Additionally, children were clustered according to patterns of emotional responses to a food model (grapefruit juice spiked with sucrose). Differences between clusters in personality traits (food neophobia, sensation seeking, curiosity trait and sensitivity to reward and punishment), and sensory responsiveness were studied.

4.3 Main results

Results from T2.2 show that preadolescents with high responsiveness to bitter and sour taste, and those with low responsiveness to sweet taste, had a lower liking for grapefruit juice. Children with the lowest responsiveness to bitterness and sourness (i.e., who did not find the taste very intense) increased their liking of grapefruit juice in parallel with the addition of sucrose. Taste sensitivity was also associated with the liking of fatty food. These results indicate that individual differences in taste and fattiness sensitivity can influence the food liking of preadolescents. In contrast with the grapefruit juice, children expressed little hedonic variations for the vegetable broth, despite clear significant variations in taste responsiveness for the same samples. This suggests that the relationship between taste responsiveness and liking is taste-, product- and subject-dependent. Moreover, our results confirmed that sweet taste

has a significant positive effect towards children's liking while sour and bitter have the contrary effect (Ervina et al., 2021b).

Further, fattiness sensitivity showed to significantly influence stated liking of fatty foods in 11-year-old children. No significant influence of taste sensitivity was found on the children's stated liking for 30 selected food items, which was strongly driven by basic taste profiles and fattiness (Ervina et al., 2020b). No correlation was found between children's taste identification ability and their liking in unfamiliar foods (Ervina et al., 2020a).

A positive association was revealed between higher taste detection thresholds (lower sensitivity) and higher food approach character traits. There was no relationship between children's taste sensitivity and their food consumption frequency as reported by the parents. However, children differed according to their BMI for the consumption frequency of dairy foods. Further, our results highlighted a positive relationship between children's BMI and food approach behaviour, and a negative relationship between BMI and food avoidance. This study also confirmed a positive association between food familiarity and stated liking. A gender effect was observed for familiarity and neophobia, where boys were more neophobic and had lower familiarity scores compared to girls (Ervina et al., 2021a).

Results from studies 4 and 5 carried out in Norway and in Italy indicated different patterns in children's emotional responses to food. Emotional patterns relate to individual differences in liking of food varying in sweetness and in responsiveness to sweet, bitter, and sour tastes (Sick et al, 2022a). Furthermore, differences in personality traits (food neophobia and sensitivity to reward) according to emotional response patterns have been highlighted (Sick et al, 2022b).

4.4 Conclusion

Through different studies T2.2 investigated the role of sensory sensitivity in the formation of food preferences, in relation to individual characteristics (gender, Food neophobia, BMI), liking and food-elicited emotions. The results highlight that preadolescents have higher preferences for fattiness and sweetness in foods and an aversion to bitterness and sourness; however these main lines are modulated at individual level with fattiness sensitivity and taste responsiveness to bitterness and sourness.

Moreover, differences in emotional responses to food were associated with differences in liking, taste sensitivity and, to a lower extent, personality traits. These results call for further research on these aspects to better understand preadolescents' food-related behaviour and to develop strategies aimed at boosting the adoption of healthier food habits targeted at specific clusters of preadolescent children. With regards to psychological traits, BMI was positively associated with food approach behaviour and negatively associated with food avoidance. Furthermore, boys were more neophobic than girls.

In summary, this research contributes to a better holistic understanding of taste and fattiness sensitivity in connection to food liking and personality traits in preadolescents. The results call for the development of different strategies specific to children's taste responsiveness profiles, to increase their acceptance for foods dominated by warning sensations of sourness and bitterness such as fruits and vegetables.

Furthermore, findings can be used to not only understand children's food behaviour but also to develop novel products targeted at specific clusters of children considering their individual differences in emotions, personality traits and sensory responsiveness by providing tailor-made products.

4.5 Further reading

Ervina (2021). Taste sensitivity and food liking in preadolescent children. PhD thesis. Faculty of Chemistry, Biotechnology and Food Science, University of Life Sciences, Ås, Norway

Ervina, E., Almli, V. L., Berget, I., Spinelli, S., Sick, J., & Dinnella, C. (2021). Does responsiveness to basic tastes influence preadolescents' food liking? Investigating taste responsiveness segment on bitter-sour-sweet and salty-umami model food samples. *Nutrients*, *13*(8), 2721.

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5 Conclusion

In conclusion, the work conducted in WP2 demonstrates that preadolescents vary in their response across different basic tastes and that these individual differences influence their food preferences and choices. In particular, we found that sucrose addition is an efficient suppressor of sourness and bitterness in subjects highly sensitive to sweetness and poorly sensitive to sourness and bitterness, but not in subjects with opposite responsiveness traits. These results are relevant to nutritionists and food developers aiming at tackling bitterness and sourness rejection in children.

The results also suggest that taste sensitivity is multi-faceted, with poor correlations between, for example, detection threshold and taste responsiveness. Moreover, as the first study including two bitter compounds in taste sensitivity testing of preadolescents, our results revealed significant discrepancies in taste sensitivity for caffeine and quinine. These findings show the importance of measurement method and bitter stimulus selection in taste sensitivity and taste acceptance studies. Finally, this work highlights that taste sensitivity on its own poorly explains food preferences of preadolescents: Multiple factors contribute to forming food preferences, including (among others) food familiarity, food neophobia, and food approach/food avoidance personal traits.

The usage of remote sensory testing as an alternative approach for sensory data collection in preadolescents is suggested for further studies. Data collection of emotional responses to food appears to be a promising tool for a deeper understanding of children's food behaviour and preferences. Further research may investigate if the associations uncovered between taste sensitivity and food acceptance are stable across different model food samples, basic tastes, and cultures.

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