Norwegian University of Life Sciences
Faculty of Chemistry, Biotechnology
and Food Science

Philosophiae Doctor (PhD)
Thesis 2021:89

New methodologies in sensory and consumer research with preadolescents to guide product development of healthy, child-centred food

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"A factor that complicates work with children is the simple fact that their perspectives are very different from those of the adult practitioners who work with them." (Petr, 1992)

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SUMMARY

Childhood obesity is one of the most serious public health challenges of the twenty-first century (WHO, 2018). In this context, finding ways to make the healthier food choices the preferred ones, can be a valuable contribution to solving this multifaceted problem, as currently the majority of food marketed to children is unhealthy. Sensory and consumer methodologies are needed to support the development of healthy products that children will like and actively chose.

This PhD thesis aimed to establish research-based knowledge on new suitable consumer insight and food testing methodologies with preadolescents. Children in this age group (appr. 9 to 12 years old) are becoming more autonomous, so the study of their self-directed food choices is highly relevant.

Co-creation was explored with preadolescents for the first time in a food context. The potential of co-creation to develop healthier food that children would enjoy and choose was introduced in an opinion paper. Further, a methodological approach applicable to early stages of new product development was proposed for the ideation of healthy food concepts based on case studies in two settings, focus groups and online. Results provided first indications that children could develop concepts for healthy food in co-creation settings. The participative, explorative format was particularly engaging for children.

Two novel indirect methods were studied and compared to traditional questionnaire-based methods: implicit testing and biometrics. The Approach Avoidance Task (AAT) as a particularly easy implicit reaction time task assessed children's implicit approach biases to different snack pictures. Results indicated a weak correlation of implicit bias to their expected liking ratings. Implicit testing seemed to be more related to concrete situational food preferences due to hunger state. Further, a procedure to facilitate a standardized self-administered tasting by children was established for facial decoding as biometrics measurement. Apart from implicit facial expressions, children were asked to explicitly indicate with their faces how they felt about the tasted sample. Implicit as well as explicit basic emotions correlated with liking ratings, but explicit facial expressions were the most discriminative measurement.

Further, Check-all-that-apply (CATA), an easy method to generate sensory descriptions of food products, was studied with children regarding individual differences in data quality according to ticking style (the way children used the CATA list). Children's approach to the CATA task was studied by defining ticking style indicators: number of ticks, standard deviation of number of ticks per sample, and number of different attributes used in the test. Three groups of children were unveiled. Differences among groups may reflect different cognitive development levels. The findings highlighted, that the CATA method was more suitable for older children of the study (8 to 9 y. o. compared to 6 to 7 y.o.) but that individual differences in cognitive development within age group occurred.

This thesis provides novel methodologies with age-specific recommendations on how to include preadolescents in sensory and consumer studies which can serve the food industry as well as research for better understanding children's perception of food and food testing procedures.

SAMMENDRAG

Ifølge WHO er fedme i barndommen en av de alvorligste folkehelseutfordringene i det tjueførste århundre. I denne sammenhengen kan det å finne måter å gjøre de sunnere matvalgene til de foretrukne, være et verdifullt bidrag til å løse dette mangefasetterte problemet, spesielt tatt i betrakting at mesteparten av maten som markedsføres til barn i dag er usunn. Sensorikk- og forbrukermetoder er nødvendige for å støtte utviklingen av sunne produkter som barn vil like og selv aktivt velge.

Denne doktorgradsavhandlingen hadde som mål å etablere forskningsbasert kunnskap om ny og hensiktsmessig forbrukerinnsikt og metoder for testing av mat med barn (ca. 9 til 12 år). Barn i denne aldersgruppen blir mer selvstendige, så studiet av deres selvstyrte matvalg er svært relevant.

For første gang i matsammenheng ble co-creation utforsket med minitenåringer. Potensialet for co-creation for å utvikle sunnere mat som barn vill sette pris på og velge, ble introdusert i en *opinion paper*. Basert på casestudier i to ulike situasjoner: fokusgrupper og on-line, ble det videre foreslått en metodisk tilnærming som kan brukes i tidlige faser av produktutviklingen av nye produkter, både for å frembringe og utvikle ideer til sunne matkonsepter. Resultatene ga de første indikasjonene på at barn kunne utvikle konsepter for sunn mat under co-creation-situasjoner. Det deltakende og utforskende formatet var spesielt engasjerende for barn.

To nye indirekte metoder ble studert og sammenlignet med tradisjonelle spørreskjemabaserte metoder: implisitt testing og biometri. Tilnærmings- og unngåelsesoppgaven (Approach Avoidance Task, AAT) som en enkel implisitt reaksjonstidtest, vurderte barns implisitte tilnærmingsbias til forskjellige snacksbilder. Resultatene indikerte en svak korrelasjon av implisitt bias i forhold til deres forventede smaksvurderinger. Implisitt testing syntes å være mer relatert til konkrete situasjonsbetingete matpreferanser, for eksempel knyttet til sultstilstand. Videre ble det etablert en prosedyre for å muliggjøre en standardisert selvadministrert smaksprøving for barn med biometri-måling i form av ansiktsavkoding. Bortsett fra implisitte ansiktsuttrykk, ble barna bedt om å uttrykkelig angi med ansiktet sitt hva de følte for smaksprøven. Implisitte så vel som eksplisitte grunnleggende følelser korrelerte med smaksvurderinger, men eksplisitte ansiktsuttrykk var den mest differensierende målingen.

Check-all-that-apply (CATA) er en enkel metode for å frembringe sensoriske beskrivelser av matvarer. Metoden ble benyttet med barn for å undersøke individuelle forskjeller i datakvalitet i henhold til brukt avkryssingsstil (måten barn brukte CATA-listen på). Barnas tilnærming til CATA-oppgaven ble studert ved å definere indikatorer basert på avkryssingsstil: antall avkryssing, standardavvik for antall avkryssinger per prøve, og antall forskjellige egenskaper som ble brukt i testen. Tre barnegrupper ble avdekket, og forskjeller mellom grupper kan gjenspeile forskjellige kognitive utviklingsnivåer. Funnene understreket at CATA-metoden var mer egnet for eldre barn (8 til 9 år), men at individuelle forskjeller i kognitiv utvikling i aldersgruppen forekom.

Denne avhandlingen presenterer nye metoder med aldersspesifikke anbefalinger for hvordan barn kan inkluderes i sensorikk- og forbrukerforskning. Metodene kan brukes overfor næringsmiddelindustrien, samt innenfor forskning for å bedre forstå barns oppfatning av mat og prosedyrer for mattesting.

CONTENT

SCIENTIFIC CONTRIBUTIONS

PAPERS INCLUDED IN THE THESIS

Paper 1 Children as food designers: The potential of co-creation to make the healthy choice the preferred one

Paper 2 Listening to children voices in early stages of new product development through co-creation – creative focus group and online platform

Paper 3 Children's sweet tooth: explicit ratings vs. implicit bias measured by the Approach avoidance task (AAT)

Paper 4 Capturing food-elicited emotions: facial decoding of children's implicit and explicit responses to tasted samples

Paper 5 How children approach a CATA test influences the outcome. Insights on ticking styles from two case studies with 6–9-year old children

OTHER SCIENTIFIC CONTRIBUTIONS

Conferences

2020 15th Sensometrics meeting (virtual conference)
oral presentation

10th European Conference of Sensory and Consumer Research (EuroSense) (virtual conference)
two oral presentations (E3S student award)

2021 18th Nordic sensory workshop (virtual conference)
poster and flash presentation (award: best student contribution)

ISBPNA, Advancing Behavior Change Science Xchange Initiative (virtual conference)
oral presentation

Pangborn Sensory Science Symposium (virtual conference)
flash presentation in Early Career Seminar and poster

Creative Tastebuds symposium (Ebeltoft, Denmark)
scientific abstract

Collaborative papers

Velázquez, A. L., Galler, M., Vidal, L., Varela, P., & Ares, G. (2022). Co-creation of a healthy dairy product with and for children. *Food Quality and Preference, 96*, 104414. https://doi.org/https://doi.org/10.1016/j.foodqual.2021.104414

Fismen A-S, Galler M, Klepp K-I, …,Helleve A. Weight status and mental well-being among adolescents: the role of self-perceived body weight. A cross-national study. Submitted to *Adolescent Health*

ABBREVIATIONS

AAT	Approach Avoidance Task
ANOVA	Analysis of Variance
BMI	Body Mass Index
CA	Correspondence Analysis
CATA	Check-all-that-apply
DoE	Design of Experiment
IAT	Implicit Association Task
MFA	Multiple Factor Analysis
NPD	New Product Development
PCA	Principal Component Analysis
PCR	Principle Component Regression
QDA	Quantitative Descriptive Analysis
UNICEF	United Nations Children's Fund
WHO	World Health Organization

INTRODUCTION

“If food systems deliver for children, they are delivering for us all.” (UNICEF, 2019)

Children's diets are composed of too much calorie-dense food high in sugar, fat, and salt, containing not enough other nutrients and dietary fibre (UNICEF, 2019). In combination with shifts to more sedentary lifestyles, unhealthy diets are responsible that overweight and obesity prevalence has increased dramatically into a major global health crisis in recent decades (WHO, 2018). While overweight has long been seen as a problem in wealthy countries, the problem is now growing in low- and middle-income countries as well. In 2018, 18 % of 5-19-year-old children were living with overweight or obesity worldwide while it was only 10 % in 2000 (UNICEF, 2019). Overweight and obesity can affect a child's immediate health and wellbeing and pose a higher risk to develop cardiovascular diseases, type 2 diabetes, and cancer later in life (WHO, 2018). Moreover, preferences and habits formed during childhood tend to last into adulthood (Nicklaus, 2016).

The steep increase of overweight and obesity prevalence worldwide clearly shows that healthy diets go beyond individual responsibility and today’s obesogenic environments need to be tackled from different angles. Particularly children, as vulnerable group need to be supported by measures that ensure that healthy food choices are easy as well as attractive for them. In today’s globalized food systems, food companies have a tremendous power to enhance the dietary quality of children, but the majority of food marketed to children is unhealthy. In this sense, new product development of food which considers children’s nutritional needs and preferences presents an opportunity for food producers to take action to the global challenge.

For child-centred solutions, sensory and consumer methodologies are needed to study what drives children's healthy food choices. This takes into account more than formulation alone, looking into both intrinsic and extrinsic product properties. Furter, design-driven co-creation that uses the voice of the children as consumers to develop healthier products offers a new approach to healthy new product development.

1 THEORETICAL BACKGROUND

1.1 CHILDREN'S FOOD ENVIRONMENTS

Many children live in obesogenic food environments that obstruct healthy food choices[1] (Engler-Stringer et al., 2014; Osei-Assibey et al., 2012; UNICEF, 2019). The Innocenti Framework by UNICEF identifies some key points in the food system where action can be taken (Figure 1) (Raza et al., 2020; UNICEF, 2019). Food system perspectives are highly complex. In the following, a selection of relevant factors will be addressed.

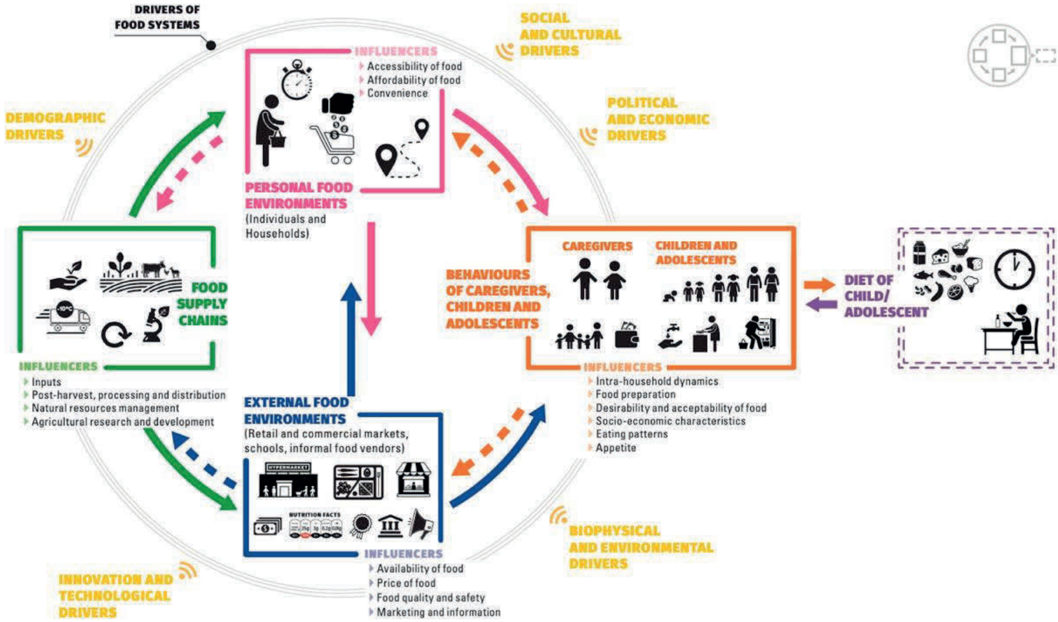

Figure 1: A food-system analysis by the Innocenti Framework (UNICEF, 2019). From "(Raza et al., 2020)" by A. Raza et al., 2020, *Global Food Security*, 27, p. 100436. Copyright by Elsevier

1.1.1 Food supply and external food environments

Through urbanization and demographic shifts, the retail sector has changed from small local shops and open markets to supermarkets (Ares et al., 2021). Food production today is in the hands of a relatively small number of multinational businesses, 100 firms account for 77 percent of processed food worldwide (UNICEF, 2019). In such settings, packaged and processed food that ensures safety and efficient distribution is more common and in some cases, the availability of

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[1] A healthy diet should contain fruits, vegetables, whole grains, fibres, nuts, and seeds and should limit free sugars, sugary snacks and beverages, processed meats, saturated and industrially-produced trans-fats, and salt (UNICEF, 2019). National dietary guidelines provide recommendations adapted to countries-specific food contexts.

fresh food can be limited. Children are targeted as a specific profitable market segment by the food industry (ReportLinker, 2021). But unfortunately, healthy food is particularly underrepresented in the child food sector as studies in different countries showed (Chacon et al., 2013; Elliott, 2019; Gimenez et al., 2017; Lavrisa & Pravst, 2019; Mehta et al., 2012). Children's preferences are shapes by elaborate marketing strategies including packaging design, advertisement, and placement strategies. For example, high sugar products are often marketed as fun and appropriate for children (Velázquez et al., 2021).

Currently, different public health measures such as sugar taxation, front-of-pack nutritional labelling or warning as well as banning the marketing of unhealthy food to children are debated and implemented in different countries to correct market failure (WHO, 2018). For example, Chile has launched a National Food and Nutrition Policy where front-of-pack nutritional warning labels and banning of marketing of unhealthy food to children were implemented among other measures.

1.1.2 Personal food environments and behaviour of caregivers and peers

Children's preference patterns are shaped through availability, exposure, and modelling of eating behaviour by caregivers and peers. Besides parental influences, schools and day-care settings play an important role in providing meals for children as in many households both parents work. Therefore, important influence factors will be summarized in a broader sense.

Exposure to and availability of healthy food

Children innately like sweet tastes and avoid bitter and sour-tasting food which from an evolutionary perspective ensured sufficient calorie intake and prevented poisoning (Forestell, 2017; Savage et al., 2007). However, in environments with high availability of food, these preferences are no longer an adaptive advantage.

Exposure is considered the most important factor in shaping children's diets. Many fruits and vegetables contain certain levels of bitterness and therefore, and learning to tolerate them enables children to eat more healthily. Children can learn to like food through positive and repeated experiences (Lafraire et al., 2016; Savage et al., 2007). Aroma compounds of mothers' diets are surpassed in the amnionic fluid and breast milk building a "flavour bridge" which can promote the infant's acceptance of foods from the maternal diet (Savage et al., 2007). Once children start to eat food, repeated exposure is known to enhance children’s acceptance but requires a certain persistence by caregivers (Savage et al., 2007). Ensuring the availability and accessibility of healthy food such as fruits and vegetables at home and in schools is known to increase preference as well as intake (DeCosta et al., 2017; Savage et al., 2007).

Certain settings might be particularly suitable to create stimulating exposures. Hands-on experiences such as cooking classes, gardening and playful and creative exploration (examples are presented in Figure 2) have been effective in increasing children’s willingness to eat initially rejected food such as fish or vegetables (Allirot et al., 2016; DeCosta et al., 2017; Højer et al., 2020).

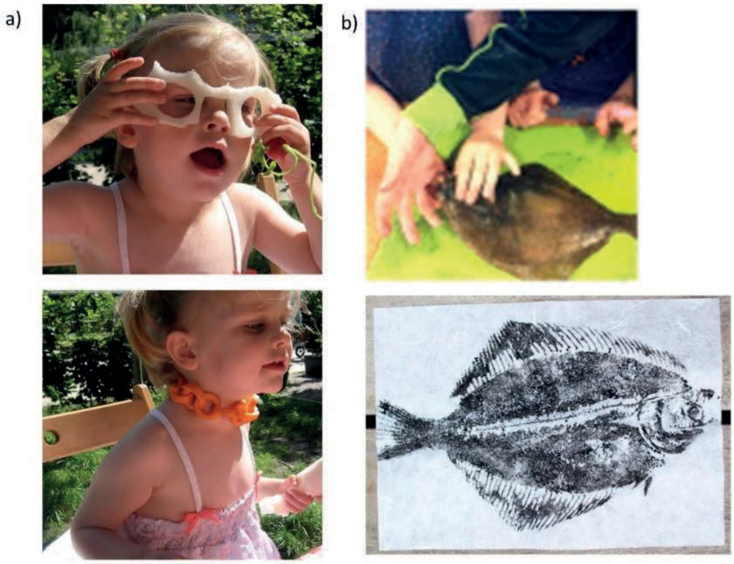

Figure 2: Cooking and tactile play to overcome food rejections. a): Design intervention "Veggi Bling Bling": children create jewellery out of vegetables by using their teeth. By Marije Vogelzang. Retrieved from https://www.marijevogelzang.nl/past-projects/veggie-bling-bling/ with permission to reprint. b): Fish printmaking and cooking intervention to help children overcome aversion against fish. From “Play with Your Food and Cook It! Tactile Play with Fish as a Way of Promoting Acceptance of Fish in 11- to 13-Year-Old Children in a School Setting—A Qualitative Study”, by R. Højer, K. Wistoft, M.B. Frøst, 2020, *Nutrients*, 12, CC BY-NC-ND

Restriction of unhealthy food

In the context of overabundant food environments, permissive feeding approaches, that leave all the choices to the child are associated with higher sugar consumption and higher BMIs (Shloim et al., 2015). There might be several reasons for permissive approaches. Parents and other caregivers might lack adequate knowledge of what a healthy diet is. The value of healthy eating might compete with other values such as fostering family and peer relationships (Roberts & Pettigrew, 2013; van der Heijden et al., 2021). For example, in families with low socioeconomic positions, fulfilling children's inexpensive food requests might offer a way to compensate for other material constraints (Fielding-Singh, 2017).

But also, over-controlling approaches not responsive to children's preferences have been reported to be problematic increasing preference for unhealthy restricted food and undermining the learning of self-regulation which becomes more important as children grow older (Shloim et al., 2015). While restrictive strategies might be successful in the short term, the efforts might not last: Campbell et al. (2010) found that parental restriction of children's access to unhealthy food was associated with lower BMIs in young children (5-6 y. o.), but not in preadolescents (10-12 y. o.).

Feeding strategies that have children's healthy eating in mind but are responsive to children's preferences have been found most effective in shaping healthy eating patterns (Shloim et al., 2015). From a motivational perspective, offering children a choice has been shown to increase their intrinsic motivation, effort, task performance, and perceived competence (DeCosta et al., 2017; Patall et al., 2008).

Modelling

Children learn what is acceptable to eat by observing others. Therefore, the cultural context, as well as the preference patterns of caregivers, siblings as well as peers, play an important role (Savage et al., 2007). In social settings such as schools, peers' preferences are particularly important (Roberts & Pettigrew, 2013; Waddingham et al., 2018). However, studies mainly found peer influence to have a negative effect on children's healthy eating (Rageliene & Gronhoj, 2020). In a grounded theory study that explored 8-12-year-old Australian children's eating at school a consumption hierarchy of was found which divided food in low and high-status (Figure 3): generic brands, fruits, vegetables, and unfamiliar food were perceived as low status while promoted food, canteen food as well as food high in sugar, salt or fat were perceived as higher status. Parents reported giving in to providing their children high-status food at school so they would "fit in".

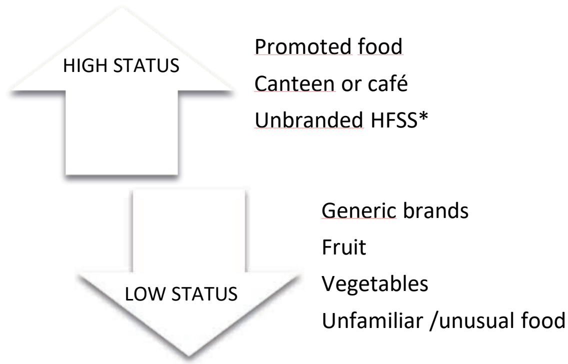

Figure 3: The consumption hierarchy of food in the school of 6-12 y.o. Australian children and their parents *HFSS: food high in fat, sugar, or salt. From "Psychosocial influences on children's food consumption.", by M. Roberts, S. Pettigrew, 2013, *Psychology & Marketing*, 30, p.103-120, CC BY-NC-ND

1.2 CHILDREN'S FOOD CHOICES

Children's food choices are generally limited through availability defined by their food environment, particularly their primary caregivers. However, it is useful, to understand how to encourage children's self-directed choice of healthy food for several reasons: As mentioned above, a restrictive approach might not always lead to the desired effects.

Children can influence purchasing decisions through “pester-power” as secondary consumers (Nicholls & Cullen, 2004). And during preadolescence, children become more autonomous in their food choices which might include purchases at the grocery store and in school canteens as primary consumers (Hill, 2002; Warren et al., 2008).

Food choice is influenced by many interacting factors. Besides product properties, the child as consumer and the context in which the child comes in contact with food play a role. Köster and Mojet (2018) described intrinsic and extrinsic product properties, physiological and psychological individual factors as well as situational and sociocultural context factors (Figure 4) which will be addressed in the following paragraphs.

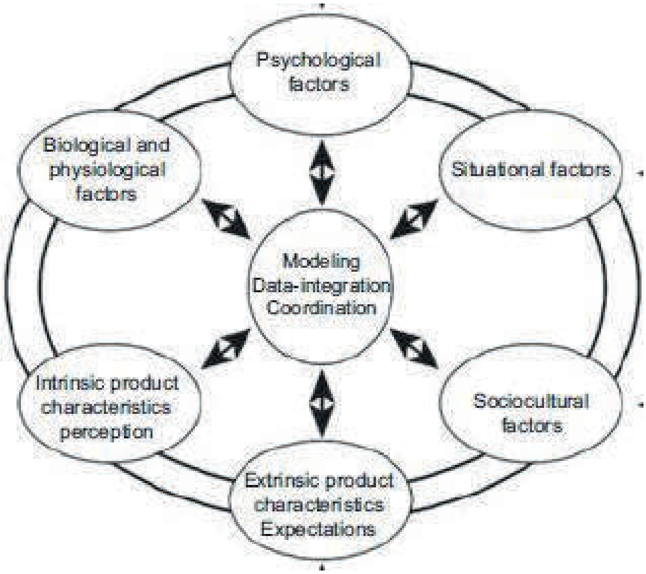

Figure 4: Food choice is influenced by interacting factors: intrinsic and extrinsic product properties, children's physiological and psychological characteristics as well as the situational and socio-cultural context. From “Diversity in the determinants of food choice: a psychological perspective”, by E.P. Köster, 2009, *Food Quality and Preference*, 20, p. 70-82. Copyright by Elsevier

1.2.1 Product properties: Extrinsic and intrinsic factors

Extrinsic product properties

Extrinsic product properties such as brand, packaging design, and health claims are not part of the physical product itself but decisive factors of food choices (Asioli et al., 2017). Extrinsic factors are mainly relevant in packaged food. Food targeted at children usually uses playful design elements such as cartoon characters (Figure 5a), bright colours, and certain fonts to attract their attention (Ares et al., 2021). Playful packaging design is decisive for children's choice and could potentially be used to market healthy food to children (Ares et al., 2021). The focus on fun in the context of eating has, however, been criticized in general as it might change children's relationship to eating and lead to overconsumption (Elliott, 2015).

Nutritional claims mainly target parents who buy food for their children. However, children might avoid products with health claims if they lead them to assume reduced pleasure (Grendstad, 2020; Mikkelsen, 2020; Nicklaus, 2016; Wardle & Huon, 2000). For example, the claim "No added sugar" had a negative effect on children's liking and choice of chocolate milk, probably because it led them to assume reduced sweetness (Grendstad, 2020; Mikkelsen, 2020). On the other hand, conjoint studies have implicated that front-of-pack labelling by the Chilean warning system (Figure 5b) discouraged children from choosing products with excessive fat or sugar contents (Arrúa et al., 2017). The authors hypothesized that warning labels take the focus away from indulgence, but more research is needed to understand the mechanisms for children's decision making.

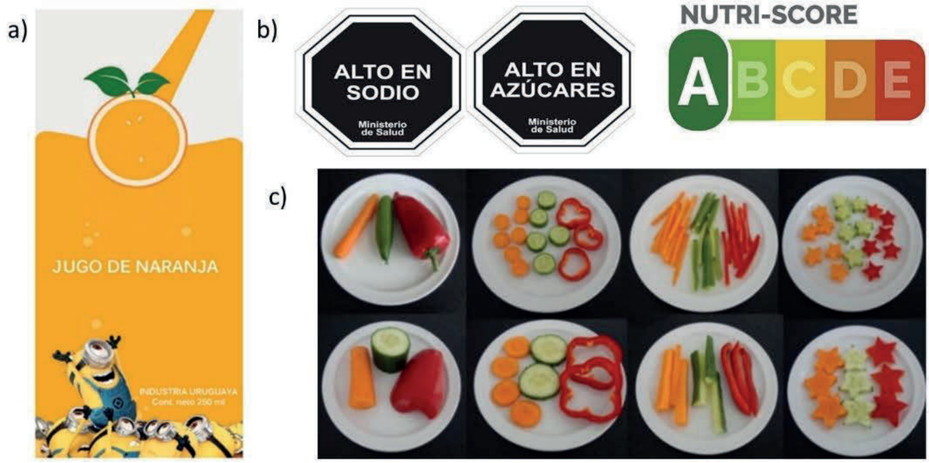

Figure 5: Visual product properties that can influence children's food choices: a) playful packaging design with a cartoon character. From "Impact of front-of-pack nutrition information and label design on children's choice of two snack foods: Comparison of warnings and the traffic-light system" by A. Arrúa et al., 2017, *Appetite*, 116, p. 139-146. Copyright by Elsevier, b) Front-of-pack food labels (left: warning "high in sugar/salt/fats/calories", right: Nutri-score: assessment of overall healthiness) From "Front-of-package food labels: A narrative review" by N.J. Temple, 2020, *Appetite*, 144, p. 104485. Copyright by Elsevier. c) vegetables cut in different shapes. From "Serving styles of snack vegetables. What do children want?" by A. Olsen et al., 2012, *Appetite*, 59, p. 556-562. Copyright by Elsevier

Intrinsic product properties

Intrinsic product properties influence the sensory perception of the food itself. Sensory perception of intrinsic properties consists of different modalities: appearance (vision), basic taste perceived on the tongue, smell (ortho- and retronasal) as well as texture (vision and mouthfeel). Previous research has highlighted several intrinsic factors that influenced children's choices.

An appealing presentation of food can be decisive for children's willingness to try it. Cutting vegetables into pieces increases children's liking, particularly for certain shapes (Figure 5c) (Olsen et al., 2012). And also the plating of food mattered and preferences differed from adults (Zampollo et al., 2012). Children generally prefer higher sweetness levels than adults and tend to reject bitter taste more. And also texture is an important driver of children's food choices (Lafraire et al., 2016; Waddingham et al., 2018). Children tend to prefer soft and uniform compared to granular and lumpy food (Laureati et al., 2020; Lukasewycz & Mennella, 2012). Texture preferences change with age as the mouth muscles, jaw and teeth develop. Particularly, young children tend to reject food that is difficult to manipulate in the mouth (Lukasewycz & Mennella, 2012; Szczesniak, 1972). Sensory modalities interact with each other. For example, the addition of vanilla aroma and starch to a milk dessert could compensate sugar reduction regarding children's sweetness intensity perception as well as liking (Velázquez et al., 2020b).

1.2.2 Children as consumers: physiological and psychological factors

Children's food choices are influenced by physiological as well as psychological factors which might vary between children. But there are some relevant common patterns which can enable or prevent healthy choices.

Many young children tend to reject certain tastes and textures in food, described as picky/fussy eating, and show a reluctance to try unfamiliar, new food, described as food neophobia (Dovey et al., 2008; Lafraire et al., 2016). Typically, food neophobia and pickiness levels peak around the age of two and gradually decrease thereafter (Dovey et al., 2008). Food neophobia and the innate disliking of bitterness could be evolutionarily beneficial to prevent toddlers who start moving around on their own but lack the knowledge of what is edible to eat something poisonous (Crane et al., 2019; Mennella & Bobowski, 2015). Under the right conditions, children's food neophobia and pickiness decrease over time, and preferences expand towards more acquired tastes. A strong and persistent expression of food neophobia, as well as picky/fussy eating, is associated with lower dietary variety which could hinder the intake of certain nutrients (Cooke et al., 2006; Falciglia et al., 2000; Kutbi et al., 2022; Maiz & Balluerka, 2016) as well as the participation in social gatherings around food (Thompson et al., 2015).

In their food choices children generally put a high focus on pleasure and are not likely to consider long-term health effects if they associate them with reduced pleasure (Marty et al., 2018; Olsen, 2019; Pettigrew, 2016; Roberts & Pettigrew, 2013). A gambling task assessing long-term decision making according to developmental stage found that preadolescence (10-12) was only slightly advanced compared to younger children (6-9) and disadvantaged compared to young adults regarding their ability to make long-term advantageous choices independent of cognitive skills in other domains (Crone & van der Molen, 2004). The late development of areas in the prefrontal cortex is thought to be linked to children's difficulty in anticipating long-term outcomes and controlling reward-driven behaviours (Crone & van der Molen, 2004; Lowe et al., 2020). From a public health perspective, children can be considered as low agency individuals who benefit least from health interventions appealing to individual responsibility, e.g. consulting calorie labels and ingredient lists on food packaging for their food choices (Adams et al., 2016).

1.2.3 Context: Situational and sociocultural factors

There are situational factors as well as sociocultural factors that influence food choice. As seen in the previous subchapter (2.1. Children's food environment), children's preferences and habits are shaped by their food environment. External and personal food environments define what is available and desirable. Besides these more static factors, situational factors, e.g. eating with peers or eating with the family, shape what a child finds appropriate to eat at a specific moment. Situational appropriateness is therefore an important factor in understanding food choices (Giacalone & Jaeger, 2019).

1.3 CHILD-CENTRED NEW PRODUCT DEVELOPMENT

Children pose a challenging consumer segment that is not easily convinced to choose the healthy option. The understanding of product characteristics, the targeted consumer group, as well as relevant consumption context as central factors of food choice, are key to develop products that are close to the child's needs, ensuring a child-centred approach. Food industry and gastronomy (particularly school canteens) should strive to acquire direct input from children for the development of healthy food choices.

1.3.1 New product development stages

Consumer research can be included at different stages of the new product development (NPD) process (Figure 6). Several authors have stressed the need to involve consumer's voices from the early stages of NPD to develop successful and innovative consumer-centred products (Grunert et al., 2011; van Kleef et al., 2005; Veflen, 2014). The early stages of NPD consist of opportunity identification, idea generation, and concept screening stages (van Kleef et al., 2005). In later stages, prototypes can be tested to optimize product properties. Once on the market, products might be monitored to ensure satisfaction. Each phase can be iterative including several cycles.

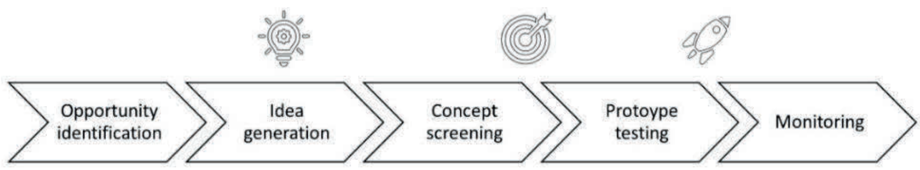

Figure 6: Stages of new product development that can be informed by consumer research

1.3.2 Different levels of involvement

Druin (2002) described how children have been involved in new product development historically from passive to more active roles: users of existing products, testers of prototypes, informants throughout the design process, and design partners (Figure 7). Her work was based on the design of new technology but the description applies to the food context where studies with direct input from children have become more common (Laureati, Pagliarini, et al., 2015). For example, in a study comparing parent-reported and child-perceived parental feeding styles, child-perceived parental feeding style was a better predictor for their food attitudes than the parent-reported, and the authors stressed the need to collect more data directly from children (Taylor et al., 2011). However, each role has its strengths and limitations.

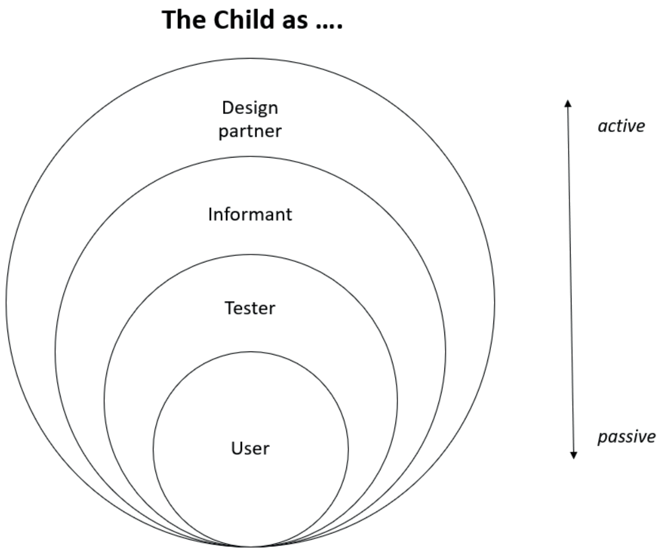

Figure 7: Different levels of involvement in NPD. The role of children in the design of new technology. From "The role of children in the design of new technology" by A. Druin, 2002, *Behaviour & Information Technology*, 21, p. 1-25. Copyright by Taylor & Francis

Methodologies for observational studies of children's interaction with food or prototypes ("The child as user or tester") would be, e.g. questionnaires filled in by parents as observers, ethnographical studies, and also biometrics measurements through video recording or eye-tracking. Results might reflect children's natural behaviour well and the indirect nature of the test procedures does not require capabilities for introspection and expression of perceptions and opinions by children. The interpreter of children's reality, e.g. parent, researcher, or machine algorithm, can however be biased.

More active forms of involvement ("The child as a tester, informant, design partner") require suitable interactive techniques to generate the desired information, e.g. through questionnaires, focus group discussions, or also online portals. For young children, images and drawing can be used to overcome verbal limitations. Many sensory and consumer methodologies fall under the categories tester and informant. The interactive aspect offers children opportunities to express their reality. Measurements could be biased through methods that are not suitable for the age group as well as social desirability effects.

The most active form, "The child as design partner", requires suitable creative brainstorming methods and a framework or pre-defined process on how to enable participation of children on eye level. Frameworks from participatory research used by social science (Clark & Jill, 2004; Davidson, 2017; Petr, 1992; Water, 2018) but also co-design initiatives (Hansen, 2017; Kelly et al., 2006; Mazzone et al., 2011) addressed inherent power structures as problematic. For example, experts who initiate a participatory project might be inclined to ignore suggestions by children if they do not fit their preconceived concepts which could lead to conflicts. Participatory approaches might be challenging to implement fully and require flexibility as well as skills by the expert, to steer them in a fruitful direction (Dindler & Iversen, 2014). Such approaches might be useful to address topics that require the re-evaluation of social norms and values. For example, Donovan (2016) used school-based co-design activities to reflect with children on sustainable consumption intending to induce a re-evaluation of current consumption practices. Empowerment and the development of agency for the addressed topic have been suggested as positive outcomes for participatory formats (Druin, 2002). In this sense, an ongoing public health EU-funded project aims to engage youth, for childhood overweight and obesity prevention, assuming that necessary public health measures to achieve behavioural change can best be defined by their participative involvement (Horizon 2020 project CO-CREATE, https://www.fhi.no/en/studies/co-create/).

The choice of the role children play in the NPD depends on resources, timeframes, and also philosophical framework of projects. A paradigm shift is taking place in the R&D towards open innovation and co-creation, involving different stakeholders including consumers (Baldwin & Hippel, 2010). The assumption is that active involvement of the user group through co-creation or crowdsourcing can produce better-accepted innovations that are closer to the consumer's needs (Busse & Siebert, 2018; Grunert et al., 2011; Schifferstein, 2015). Therefore, it could be expected that children as consumers will be involved as more active stakeholders in the future.

1.4 SENSORY AND CONSUMER TESTING WITH CHILDREN

Insights from sensory and consumer research have traditionally informed new product development and quality control but are now also applied for more basic research related to food choice which can for example inform public health. Sensory science studies human perception related to product properties while consumer research is interested in product acceptance and choice including individual and contextual factors.

Although the advantage of including direct input from children in sensory and consumer studies is acknowledged, the implementation poses challenges. Established sensory procedures need to be adapted, not only to children per se but to the specific age group involved, adopting task difficulty to their cognitive skills but also their interests. An overview of skills (language, attention span, reasoning, decision making, understanding scales, and motor skills) according to age group from the ASTM guidelines is displayed in Figure 8 (ASTM, 2003). Laureati, Pagliarini, et al. (2015) highlighted that if age-appropriate protocols are adopted, school-aged children (defined as 4-11 y. o. in their review) can participate in many traditional consumer tests and even more sophisticated methods such as projective mapping.

Age adaptations need to take into account the cognitive-developmental stage (e.g. attention span and reading skills) of the age group involved. In child-adapted sensory tests, the text is often replaced by symbols, e.g. hedonic scales which are used to assess consumer liking are often anchored with smileys instead of text, or three digit sample codes are replaced with symbols (Figure 9a). Further, gamification can be used to engage children in the task, e.g. Ervina Ervina, Ingunn Berget and Valérie Almli (2020) introduced a taste detective game to measure children's sensory sensitivity (Figure 9b). Assisting children in filling in questionnaires can ensure their understanding (Figure 9c). However, researchers and practitioners have to be aware of potential social desirability effects that could bias children's answers, as some children might adjust their answers in ways they assume will please the assisting adult. Video instructions and practice trials are valuable tools to enable self-administered tests, particularly if more advanced methods are used (see e.g. Velázquez et al. (2020a) who used two temporal descriptive methods with children).

Choosing child-friendly environments as the testing location is important to not intimidate children (Guinard, 2001; Laureati, Pagliarini, et al., 2015; Popper & Kroll, 2005). This could e.g. be directly in school or also online in the case of older children that have access to computers. It is generally advisable to conduct a pilot study with the targeted age group prior to data collection to check and optimize test protocols.

Skill/behaviour	Infant Birth–18 months	Toddler 18 months–3 years	Pre-school 3–5 years	Early readers 5–8 years	Pre-teen 8–12 years	Teenage 12–15 years
Language—Verbal, reading/written language vocabulary	Pre-verbal. Rely on facial expressions. Cannot read. Cannot write. Uses sounds, very few words.	Begining to vocalize, adult interpretation still required. Cannot read. Cannot write. Early word usage developing.	Early language development. Can observe facial expressions, respond to questions and pictures. Generally, reading and writing skills are just begining, if present.	Moderately developed verbal and vocabulary skills; understanding increases. Early reading and writing skills, may still require adult assistance for some tasks.	Very verbal—able to express themselves adequately. Reading and written language skills increase rapidly and are sufficient for most self-administered tasks	Strong language and vocabulary skills. Reading and written language skills continue to increase. Adult level in most respects.
Attention span	Gauged by eye contact	Gauged by eye contact or involvement with task, bodily movement.	Limited, but increasing. Bright colors, movement are effective.	Limited by understanding of task and interest level, challenge.	Potential attention span is increasing, but holding interest is critical.	Similar to adults, involvement and interest subject to peer pressure.
Reasoning	Limited to pain and pleasure.	Limited, but concept of 'no' becoming a factor.	Limited, but beginning to be able to know what is liked and what is not.	Developing with increased learning, cause/effect concepts	Full ability for understanding and reasoning, capable of decision making	Reasoning skills are fully developed and similar to adults.
Decision making	Does not make complex decisions	Does not make complex decisions, but 'yes'/'no' can be decisive	Limited, but concepts of what is liked and what is not strengthen. Able to choose one thing over another.	Ability to decide is increasing, but influence of adult approval is evident.	Capable of complex decisions, peer influences a factor	Fully capable of adult decision processes, subject to peer influences
Understanding scales	Does not understand scales	Does not understand scales	Understanding of simple scales beginning, sorting or identification tasks more effective	Scale understanding increasing, simple is best.	Capable of understanding scaling concepts with adequate instruction	Similar to adults
Motor skills	Possesses some gross motor skills, no fine motor skills	Rapid gains in gross motor skills, fine motor skills still limited.	Development of both gross and fine motor skills increasing.	Gross motor skills developed, fine skills becoming more refined	Hand to eye and other fine motor skills developed.	Similar to adults
Recommended evaluation techniques	Behavioral observations. Diaries. Consumption or duration measurements		Previous, plus: Paired comparison. Sorting and matching. Limited preference. Ranking. One-on-one interviews	Previous, plus: Simple attribute ratings. Liking scales—pictorial or simple word scales. Group discussions. Concept testing	Previous, plus more abstrat reasoning tasks. Hedonic scales. Discrimination tasks. Attribute scaling and ratings.	Capable of all adult evaluation techniques.
Adult involvement	Primary caregiver. Trained observer. Experimenter			Previous, plus: Self administered		Adult participation not required, unless appropriate to evaluation technique.

Figure 8: Cognitive skills of children from infancy to adolescence. From "Standard Guide for Sensory Evaluation of Products by Children and Minors" by ASTM Standard., 2003. Copyright by ASTM International

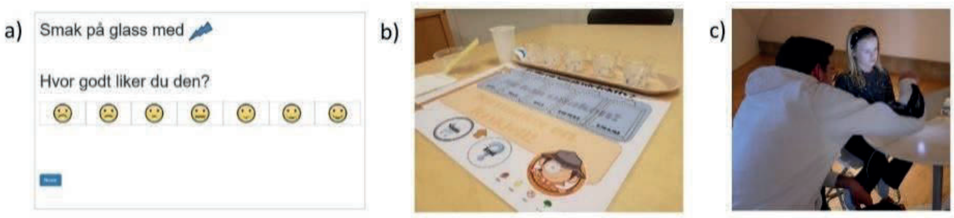

Figure 9: Example of child-adapted sensory testing: a) Hedonic scale with smileys instead of text and symbols instead of sample codes, b) storytelling/gamification. Photo by Ervina with permission to reprint. c) assistance in filling in questionnaires. Photo by Sveinung Grimsby with permission to reprint

1.5 NEW METHODS IN SENSORY AND CONSUMER RESEARCH WITH CHILDREN

Consumer interactions with food are highly complex and methods are continuously added and further developed to model food behaviour more accurately.

At the heart of sensory and consumer science stands the aim to measure the sensory perception of products. Traditional sensory descriptive methods such as quantitative descriptive analysis (QDA) are difficult to perform and therefore, only trained experts are involved. In this sense, the first review about sensory and consumer testing with children discouraged their involvement in sensory evaluations (Guinard, 2001). However, newer and simpler descriptive methods have been developed since. It is now widely accepted that the perception of objective product properties is subjective, it depends on the interpreting person (for example linked to taste sensitivity). Further, the language used by consumers to describe their perception can also inform communication strategies of products. Consumer-based descriptive methods can offer insights into children's perception and have come into application in recent years (subchapter 2.5.1.).

Early stages of new product development aim to understand the unmet needs and wants of consumers and find first ideas through creative brainstorming, often in a qualitative, exploratory way (van Kleef et al., 2005). The involvement of children in these stages might be particularly important as their needs and wants can be substantially different from adults that aim to develop products for them. But currently, suitable methods with children are missing. Early stages of new product development are often informed by focus group discussions. However, children possess more knowledge than they can express when asked directly. Through the usage of creative and enabling techniques, hidden knowledge that might not come up by directly asking children can be accessed (Figure 10). Such methods are also suitable to co-create new products with children (subchapter 2.5.2).

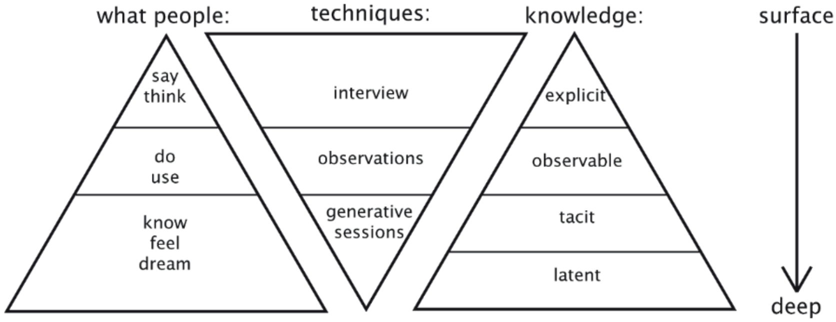

Figure 10: Different methods are needed to access different levels of knowing (extracted from Visser et al. (2005): generative sessions refer to specific techniques for early stages of new technology design. The methods described are comparable to creative and enabling methods and have come to application with children (Gielen, 2008)). from "Contextmapping: experiences from practice" by F. S. Visser et al., 2005, *Co Design*, 1, p. 122. Copyright by Taylor and Francis.

Currently, self-reported scale-based questionnaires are frequently administered to children in quantitative consumer studies. The application of hedonic scales to rate products is well established for children from 4 years old (ASTM, 2003; Guinard, 2001; Popper & Kroll, 2005) and is a good predictor of children's food choices (Lim et al., 2016). Further, there are for example food neophobia or texture preference questionnaires developed and validated specifically for children which can explain individual differences in product perception and preference (Damsbo-Svendsen et al., 2017; Laureati, Bergamaschi, et al., 2015; Laureati et al., 2020). But as Figure 10 implies, consumers and particularly children's ability to verbally express their motives for food choices is limited and potentially also biased through e.g. social desirability effects. For example, in health-related research consumers tend to report a higher health consciousness than their behaviour suggests. Therefore, indirect quantitative methods have come into application for sensory and consumer studies (subchapter 2.5.3).

1.5.1 Consumer-based methodologies for sensory characterization

There are several different consumer-based sensory methods available (Ares & Varela, 2018) of which Check-all-that-apply (CATA), sorting, and projective mapping are some of the most simple to use. Laureati, Bergamaschi, et al. (2015) suggested the application of these methods with children as promising, as they are easily understood and could be gamified.

In the check-all-that-apply (CATA) method, samples are evaluated monadically (one at a time) by ticking perceived attributes from a pre-defined list (Figure 11a). The attribute list should be easy to understand for the involved children. Preferably, the list is developed or checked in a pilot study with children of the same age group. Several studies used the CATA method for sensory characterization of food with children from 8 years old (Ervina Ervina, Ingunn Berget, Alexander Nilsen, et al., 2020; Laureati et al., 2017; Rocha et al., 2021; Sandvik et al., 2021).

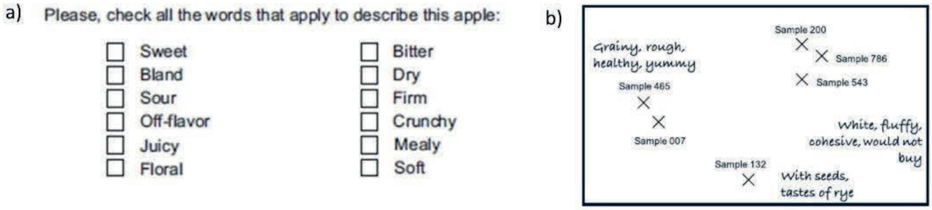

Figure 11: Sensory characterization with consumer methods a) Check-all-that-apply (CATA), b) Projective mapping. Both images provided by P. Varela with permission to reprint.

Sorting and projective mapping present holistic and exploratory approaches based on overall similarities (Figure 11b). Sorting focuses on categorization while mapping uses distances as an indication of similarity between products (Valentin et al., 2018). In a second step, consumers can be asked to describe groups or products. Individual sorting groups or maps can be overlayed by multivariate statistical approaches and descriptors can be projected onto the map (Valentin et al., 2018). Mitterer Daltoé et al. (2017) used unstructured mapping (= projective mapping) to explore 5 to 10 y. o. children's perception of fish in relation to other food items printed on stickers.

1.5.2 Creative and enabling methods

Creative and enabling methods offer an exploratory holistic way to understand children's behaviour, perceptions, and needs. Creative and enabling methods can be integrated into focus groups and are also suitable to co-create new product ideas with children. Mixing up focus groups with activity-oriented methods can increase engagement (Colucci, 2007), and depending on the method they can enhance the inclusion of introverted or shy participants. There exist a broad range of creative and enabling methods. The following paragraphs, three types, relevant to the scope of this thesis will be described.

Drawing or picture taking

Drawing and picture taking methods are often used to give children and youth a voice, e.g. to understand their physical as well as dietary environments (Figure 12a) in the context of overweight and obesity prevention (Darbyshire et al., 2005; Findholt et al., 2011; Martin Romero & Francis, 2020; Ragelienė, 2021; Woolford et al., 2012). Picture taking is part of the participatory photovoice methodology where usually marginalized groups express community concerns and expose social problems through the pictures (Sutton-Brown, 2014). While photovoice activities usually occur in life settings, Instagram has been used as a platform for a photovoice initiative with adolescents (Yi-Frazier et al., 2015).

Sorting or mapping

Due to their exploratory nature, sorting or mapping introduced in the previous subchapter are useful for early stages of new product development to assess consumer's underlying perceptions (Mesías & Escribano, 2018). Mind mapping is also used as a basis for brainstorming activities, helping participants to gain an overview and "make sense" of a topic (Gray et al., 2010). In a focus group setting, a consensus map can facilitate subsequent group discussions. Apart from sensory perception, other aspects can be addressed. For example, Varela and Salvador (2014) used a structured picture sorting task with two pre-defined axes (healthiness and tastiness) to investigate 5 to 9 y. o. children's health vs. taste perception of different depicted foods (Figure 12b).

Brainstorming and prototyping

Brainstorming requires a clearly defined goal or problem to be solved. A non-critical framework during the brainstorming is necessary to enable creative, out-of-the-box thinking (Osborn, 1953). The book "Gamestorming" (Gray et al., 2010) presents playful brainstorming techniques of which many could be adaptable for research with children. Initial brainstorming can be followed up by critical discussions or voting for the best ideas. Brainstorming can also happen online in crowdsourcing activities (Olsen & Christensen, 2015).

Brainstorming commonly uses prototypes as a visual communication tool of ideas (Guha et al., 2004; Kelly et al., 2006; Xie et al., 2012). In design thinking, prototypes enable rapid experimentation which helps the innovators to learn quickly (Olsen, 2015). The goal is to make mistakes as fast as possible and learn from them in iterative ways. Olsen, 2015 highlighted that the creative process of chefs in gastronomy but also R&D reflects prototyping well, but rarely involves end-users.

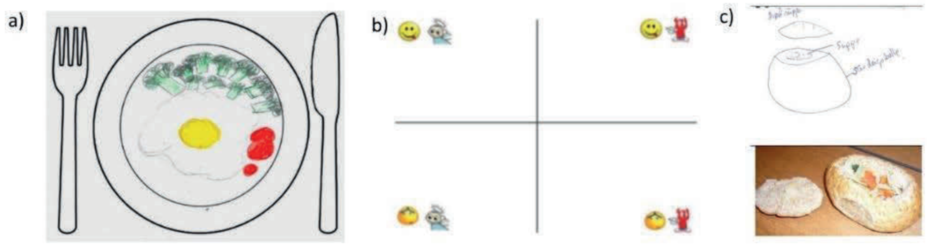

Figure 12: Example of creative and enabling methods with children: a) drawing of favorite meal in Ragelienė (2021). From "Do children favor snacks and dislike vegetables? Exploring children's food preferences using drawing as a projective technique. A cross-cultural study", by T. Ragelinene, 2021, *Appetite*, 165, p. 105276, CC BY-NC-ND, b) structured sorting template used by 5-9 y.o. children. From "Structured sorting using pictures as a way to study nutritional and hedonic perception in children" by P. Varela and A. Salvador, 2014, *Food Quality and Preference*, 37, p. 8. Copyright by Elsevier. c) Prototyping: drawing and real food. From "Design Thinking and Food Innovation", by N. Veflen, 2014, *System Dynamics and Innovation in Food Networks*, 41, CC BY-NC-ND

Food-related brainstorming has been used previously for research: Children created ideas for school meals from which researchers gained insights into their drivers of food choices (Waddingham et al., 2018). To the author's knowledge, brainstorming for new product development has not been explored with children from a research perspective so far. Figure 12c presents prototypes of a design thinking experiment where researchers and industrial partners collaborated (Veflen, 2014). The creation of real food prototypes is useful for later stages of new product development. Collaboration between chefs and children could produce food prototypes based on children's initial ideas.

1.5.3 Indirect quantitative methods

Two systems influence consumer's decision-making, a more reflective system and a more impulsive system (Figure 13). The reflective system is driven by explicit attitudes which can be measured by verbal questionnaires, the impulsive system is driven by implicit attitudes which are more difficult to access. For food choices that are often made within seconds, the impulsive system is thought to play an important role (Jacquier et al., 2012; Rangel, 2013). Köster (2009) highlighted that food habit formation occurs mostly unconsciously in childhood while conscious cognitive learning becomes more important when growing up. Methods that can capture children's automatic tendencies might therefore offer an advantage over questionnaire-based measurements that according to Köster (2009) assume reasoned action and planned behaviour.

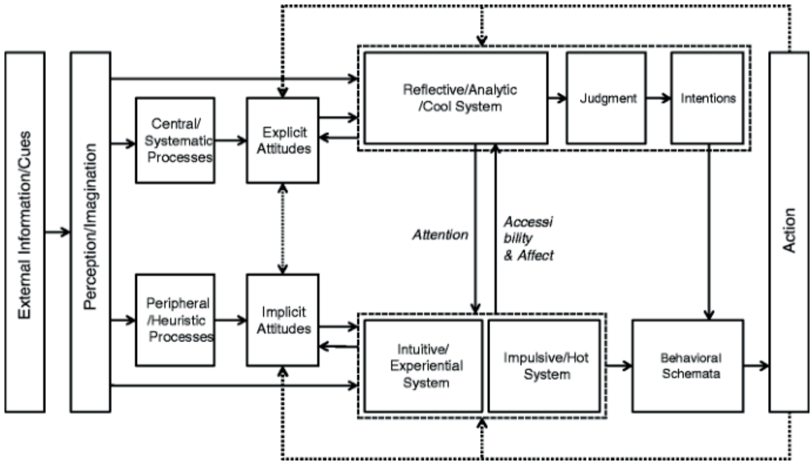

Figure 13: Dual-process model in decision making. From "Two minds, three ways: dual system and dual process models in consumer psychology", by A. Samson et a., 2012, *AMS Review*, CC BY-NC-ND. Copyright by Springer Nature

Reaction time tests to measure implicit attitudes

Methods from social psychology measuring implicit attitudes or biases have gained increasing attention to study eating behaviour (Monnery-Patris & Chambaron, 2020). Implicit attitudes have been shown to have a direct impact on eating behaviour in adults (Dubé & Cantin, 2000; Raghunathan et al., 2006) and have been postulated to be a barrier to healthy food choices (Mai et al., 2011). Implicit attitudes are often measured via reaction time tests: fast reactions indicating a congruency, slow reaction, and incongruency between presented concepts and participant's implicit attitudes. The "Project Implicit" maintains a virtual laboratory where the public can test their implicit attitudes to different topics while their data is collected for research via the Implicit Association Task (IAT): https://implicit.harvard.edu/implicit/ (Figure 14a displays test screens for the Healthy food IAT on the webpage). Many reaction time tests are cognitively challenging and require an extended attention span.

The Approach Avoidance Task (AAT) is a particularly easy reaction time task that usually is based on images. Approach and avoidance behaviour is stimulated by the pulling and pushing of a joystick in response to stimuli criteria, conveying a game-like feel (Figure 14b). Implicit approach bias occurs if an image is pulled faster than pushed. Approach bias is thought to be more closely linked to motivational wanting than evaluative liking and therefore offers a superiority towards situational food choice prediction capacity (Kraus & Piqueras-Fiszman, 2016).

Figure 14: a) Print screens of the healthy food IAT. From "Project Implicit Health" by Project Implicit Harvard, 2021, (https://implicit.harvard.edu/implicit/) b) For the approach-avoidance task the valence category (good taste vs. bad taste) is replaced by pulling and pushing of a joy: pulling faster than pushing represents approach bias. c) Adaptations for children include shorter tests and the usage of pictures instead of words. From "Healthy is (not) tasty? Implicit and explicit associations between food healthiness and tastiness in primary school-aged children and parents with a lower socioeconomic position", by A. van der Heijden et al., 2020, *Food Quality and Preference*, 84, p. 103939. CC BY-NC-ND

So far the Approach Avoidance Task (AAT) has not come into application with children in a food-related context. But there are adapted Implicit Association Task (IAT) protocols for children which consist of fewer test blocks to accommodate shorter attention spans and are based on images instead of words (Figure 14c)

(DeJesus et al., 2020; van der Heijden et al., 2020). Images have the disadvantage that they contain visual confounders, for example, the color of the depicted food could influence biases as well. However, in applications with children, images might be favourable as reading might not be fully automated. In the food-related studies, children's implicit attitudes towards healthy vs. unhealthy food were unrelated to healthy eating determined by food frequency questionnaires (DeJesus et al., 2020; van der Heijden et al., 2020) as well as weight status (Craeynest et al., 2007). van der Heijden et al. (2020) reported a lower testing power for the IAT performed by children over adults, which indicates that the performance of the simplified IAT might still be challenging for children.

Biometrics

Many physiological measurements could complement or replace explicit questionnaire-based ratings during product testing, such as measuring changes in body temperature, skin conductance, and pulse rate as well as facial expressions which can be interpreted as basic emotions via the Facial Action Coding System (FACS) (Figure 15) (Danner & Dürrschmid, 2018). Further, eye movement can be tracked to gain insights into attention and other cognitive processes during the assessment of extrinsic product properties such as packaging information (Duerrschmid & Danner, 2018). In recent years, advances in image processing and machine learning have made such measurements more efficient in generating quantitative observational data.

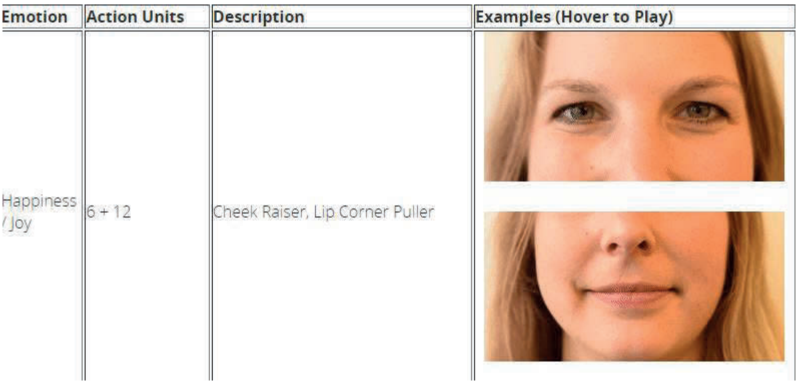

Figure 15: Facial action units (AUs) can be classified into basic emotions. An example of the basic emotion "joy" from “iMotions webpage” by iMotions, 2021, (imotions.com) with permission.

Currently, there are still limited biometrics studies with children where food was tasted. Two studies assessed children’s facial expressions in reaction to liked and disliked food and found larger effects for disliked foods (de Wijk et al., 2012; Zeinstra et al., 2009). de Wijk et al. (2012) further found some effects regarding body temperature, skin conductance, and heart rates. Sample sizes were small in both studies (n=6/16) and large product differences (high vs. low liking) were assessed, highlighting the need for further research. Eye-tracking has mainly been used to test children's attentional bias towards healthy vs. unhealthy food cues (e.g. Brand et al., 2020; Spielvogel et al., 2018).

1.6 STATISTICAL ANALYSIS

Due to the complex process underlying sensory perception and food choice, sensory and consumer methods often generate complex, multivariate datasets. Therefore, Sensometrics comes up as a key area of research, and goes hand in hand with sensory and consumer data collection method development. For instance, in the development of alternative descriptive methods with consumers, these techniques required specialised statistical methods accompanying them; e.g. multiblock methods like Multiple Factor Analysis (MFA) and DISTATIS (Valentin et al., 2018). Added to this, the analyses of individual differences comes up as an important tool when exploring consumers responses, as they are naturally divergent in their opinions, attitudes and preferences. This can be of interest not only to the industry but is also important for government agencies that want to optimize information and for researchers who aim for a better understanding of different groups in a population, for instance to better understand differences in health orientation, use of information or studies dealing with special consumer groups, like children or elderly (Berget, 2018).

Quantitative product testing generally generates a product x consumer matrix. Further, a matrix with consumer information (consumer characteristics) and a matrix with product information (product properties) can be additional blocks. Næs et al. (2018) described the structure as an L-shape structure due to the resemblance with the letter L (Figure 16). Certain sensory evaluations result in more than one consumer x product block. For example, the Check-all-that-apply (CATA) method produces a table with binary data (=block) for each attribute.

The product x consumer block represented repeated measurements. Therefore, the consumer is included as random variable in mixed Analysis of Variance (ANOVA) or other significance tests. Dimension reduction techniques, such as Principle Component Analysis (PCA) can be used to display the most important similarities and differences within a block.

To understand the drivers of food choices, it is of interest how individual characteristics such as demographics or attitudes are linked to product perception by linking the consumer characteristics block to the product x consumer block. Further, the effect of product properties (Design of Experiment factors) is of interest (product properties block).

Consumers or products can be segmented based on the similarity of their product responses (either by cluster analysis or visually via PCA or related dimension reduction methods) and then compared regarding consumer or product characteristics. Or the association between blocks can be determined. Multivariate mixed models can combine the variables from the three blocks which leads however to hierarchical dependencies between product and product properties and consumer and consumer characteristics which are somewhat difficult to model. Further, dimension reduction methods such as Principle component regression (PCR) or Multiple factor analysis (MFA) can link blocks in a more exploratory way.

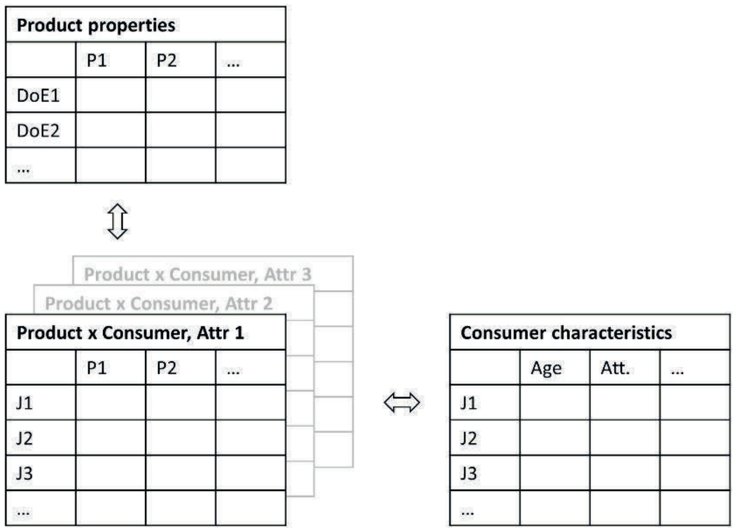

Figure 16: Typical measurement blocks of sensory and consumer science studies in three blocks: product properties, consumer characteristics, and product x consumer building an L-shaped structure (adapted from Næs et al., (2018))

There is no one size fits all when it comes to Sensometrics. There can be multiple methods applicable to analyse a specific dataset and it is important to look at the interpretation of the results obtained. In this PhD thesis, different statistical approaches were used to explore and model children's responses, and to study individual differences. Details are given in the methodological sections and supplementary material for each paper.

1.7 ETHICAL CONSIDERATIONS

Children represent a vulnerable group. Their right to participation needs to be balanced with their right to protection (Water, 2018). It is good practice to collect written parental consent and children's assent. Further, children need to be informed directly before the test that they can leave at any time without negative consequences.

Before the study data management needs to be planned. If possible test data is anonymous from the beginning. Otherwise, the time point when data will be anonymized has to be defined. This includes identifiable images or video recordings as well as other information that could enable the identification of the participant. Health-related data should only be included if it is essential for the study as it counts as sensitive data. In Norway, the Norwegian center for research data assesses registered studies regarding data management and compliance with general data protection regulation (GDPR) EU regulations.

The payment of an incentive which is common in sensory and consumer studies with adults is a controversial topic. Children are less able to weigh risk vs. benefit. Further, they are dependent on accompanying adults who might be interested in receiving the incentive. Rice and Broome (2004) provided an overview of the topic for research with children in general. In sensory and consumer research, the risk of harm through participation is generally low. Further, many sensory studies are designed in a way that children are intrinsically motivated to participate (e.g. pleasant samples and a gamified test) and therefore a nonmonetary incentive (e.g. a small gift) might be sufficient as a reward while an involvement over a longer period might require different types of incentives which could also be paid directly to a school if a whole class is involved.

For creative engagement in co-creation activities framework for participatory research with children should be consulted (Clark & Jill, 2004; Davidson, 2017; Hansen, 2017). Further, the commercial application might require intellectual property management strategies (Tekic & Willoughby, 2019).

2 RESEARCH OBJECTIVES

The thesis aim was to establish research-based knowledge on suitable consumer insight and food testing methodologies with children, aimed at the development of healthy food products (by the food industry) and a better understanding of children's perception of food (at an academic level). A special focus lay on an active engagement of children as the next generation of eaters in a changing world that requires adaption. The following objectives were addressed:

General objective:

To develop or to adapt age-specific data collection methods and corresponding statistical approaches to understand preadolescents' food choices in the context of healthy product development.

Specific objectives:

- To explore how to get direct input from preadolescents into product development (co-creation) to formulate healthy products.
- To compare classic direct methods and new indirect methods (biometrics and implicit method) with preadolescents to study responses to product properties.
- To explore consumer methods to understand the influence of product properties in children's responses to food including individual differences.

3 STRUCTURE OF THE THESIS

This PhD thesis was part of an EU funded Marie S. Curie Program, aiming at finding new ways to tackle the escalating issue of obesity in the EU and beyond, through promoting healthier eating from childhood, within the context of choice. The program covers different aspects of children and food choice as well as different age groups (see www.edulia.eu for more info). The targeted age group of the present thesis work were preadolescents. The term pre-teen or "tween" was developed in the 1980's to represent the transition of children into adolescence, being identified as a new niche from a marketing perspective (Hall, 1987). Usually defined as 9-12, the exact range can vary depending on the developmental maturity. This transition is also very important when thinking about food choices, as children are becoming more autonomous, so the study of self-directed food choices is highly relevant. All studies in this work included children between 9 to 12 years old, while paper 5 involved also younger children (6-9 y. o.).

The thesis addressed three topics:

- Co-creation as a way to engage children actively in new product development of healthy food: Paper 1 established the idea of involving children in the co-creation of healthy food and paper 2 proposed a methodological approach to involve children in the early stages of new product development via co-creation.
- Indirect methods in comparison to classic direct, questionnaire-based methods: Paper 3 introduced the Approach Avoidance Task as a particularly easy implicit reaction time task to study individual differences. Paper 4 used facial decoding as biometrics measurement for product testing.
- The assessment of the sensory characterisation method Check-all-that-apply with children (Paper 5)

An overview of topics and applications is presented in Figure 17.

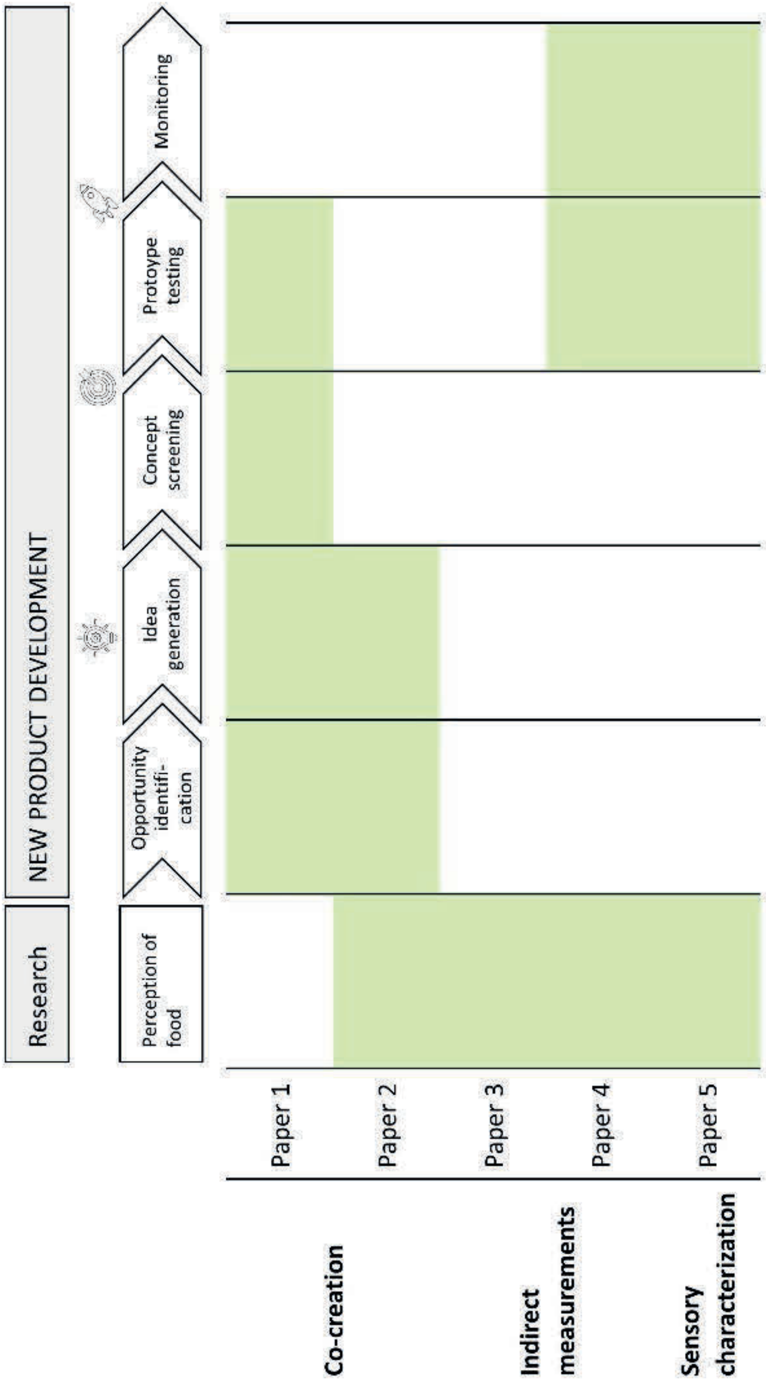

Figure 17: Structure of the thesis. Topics addressed in papers and potential applications in research and new product development

3.1 Co-creation

A paradigm shift is taking place in the R&D towards open innovation and co-creation. The active involvement of children through co-creation could potentially produce better-accepted innovations that are closer to their needs. Further, co-creation could be suitable to engage children in topics that require the re-evaluation of current social norms as healthy eating is often not desirable among peers. The papers established why co-creation could be a good approach with children and assessed a methodology based on creative and enabling methods to co-create new food ideas with preadolescents in a creative focus group and online platform setting.

Paper 1: Children as food designers: The potential of co-creation to make the healthy choice the preferred one

In this opinion paper, the idea of involving children as co-creators of food is established. It highlights that children's traditional involvement in new product development as testers could be extended to co-creators allowing active participation in the idea generation and development of healthy food. Co-creating food with children has the potential of generating ideas that adult product developers could not develop themselves. At the same time, co-creation initiatives can empower participating children to find their way to pleasurable healthy eating, thus laying the foundation for change.

The paper refers to the urban planning project "Cities of children" where the interests of children were taken as the highest priority for urban development and children were involved in participatory approaches to improve the quality of life in cities.

Paper 2: Listening to children voices in early stages of new product development through co-creation – creative focus group and online platform

This paper presents a methodology for how to involve preadolescents in co-creation activities during the early stages of new product development. As a case study, an idea for a healthy snack was developed with Norwegian children. Further, two settings were explored: creative focus groups (CFG) and online community (ONL). Three steps were defined to allow the gradual exploration of the topic and mutual learning throughout the process: (1) *Show & Tell*: photo taking and -elicitation to understand what children ate; (2) *Reflect*: a sorting task of the snack pictures collected in *Show & Tell* to discuss and reflect on snacking practices (3) *Create*: an idea generation step, in which a newspaper article describing an idea for a new healthy snack was created. To increase engagement and creativity, gamification strategies were used.

Results demonstrated that children (preadolescents) could create new food product ideas with the proposed process, using enabling and creative techniques. In the CFG the trained moderator could steer the group to the co-creation goal. The setting facilitated teamwork and group learning, collaborative ideas considering preferences of peers and produced a few detailed and mostly actionable ideas. In the ONL less control over the process was possible. The setting produced many ideas varying in the degree of detail and actionability focusing on individual preferences. The ONL can be regarded as a crowdsourcing approach. The feedback and observations from the study, particularly in the CFG setting, implied that the creative approach was highly engaging for participants. Further research is necessary to assess the potential of initial ideas.

3.2 Indirect methods

Indirect measurements aim to overcome the potential limitations of direct questionnaire-based measurements. Paper 3 introduced the Approach Avoidance Task (AAT) as a particularly easy implicit reaction time task that has not come into an application with children in a food-related context so far. In paper 4 the biometrics measurement of basic emotions via facial decoding was assessed for product testing. In both studies, indirect measurements were compared to direct, questionnaire-based measurements.

Paper 3: Children's sweet tooth: explicit ratings vs. implicit bias measured by the Approach avoidance task (AAT)

In this paper, the Approach avoidance task (AAT) to measure implicit motivational tendencies towards foods differing in *sweetness* and *calorie* content is assessed with preadolescents. Relationships between approach bias and explicit measurements of expected liking, attitudes, and hunger state were explored. Further, implicit and explicit measurements were compared to paired-preference tasks.

Children aged 9-11 participated in the study (n=114). Their implicit bias towards pictures of snacks was measured via AAT. The test instruction was based on pushing or pulling the joystick according to picture category, food vs. non-food: food (18 snack pictures varying in *sweetness* and *calorie*) vs. non-food (18 pictures visually similar to the respective food stimuli). Further, children rated their expected liking of the snack pictures, answered an attitude questionnaire related to health and sugar consumption, and completed two paired preference tests tasting real samples under blind conditions and choosing between sugar and no-sugar-added chocolate milk take-home pack.

The percentage of non-valid AAT responses was relatively high, leading to low testing power. There was a significant difference in approach bias between food pictures and non-food pictures; approach bias was positive for food and slightly negative for non-food. Within food pictures, no significant effect of *sweetness* nor *calories* was found. Nevertheless, children's approach biases were linked to their expected liking ratings, which revealed a clear preference towards high *sweetness* and high-*calorie* snacks. Individual differences in children's approach bias to pictures differing in *sweetness* and *calorie* content were related to their hunger state but not to their attitudes or preference of chocolate milk, indicating relevance for situational food choices. In the present study, questionnaire-based measurements (affective and cognitive attitude towards sugar, sugar craving and using food as a reward) were most predictive for preadolescents' preference for sugar and no-sugar-added chocolate milk. Methodological considerations and recommendations with regards to the use of approach-avoidance testing with children are critically discussed.

Paper 4: Capturing food-elicited emotions: facial decoding of children's implicit and explicit responses to tasted samples

This paper compares children's implicit and explicit basic emotions elicited by tasting, through the use of facial decoding to children's liking ratings in a case study with flavoured chocolate milk samples. Children aged 9-10 participated in the study (n=48). Six samples based on two DoE factors A*dded sugar* (yes/no) and *Surprise flavour* (peppermint/liquorice/ no added flavour) were tested. The software iMotions with the AFFDEX algorithm was used for facial decoding. For each sample, facial expression was measured immediately after tasting (implicit basic emotions). Then, children were asked to show a facial expression related to their feelings when they tasted the chocolate milk (explicit basic emotions) and rate their liking on a 7-point-scale.

Implicit and explicit basic emotion likelihoods from facial decoding were correlated to liking regarding the factor *Surprise flavour*. The measurement of implicit basic emotions discriminated samples according to negative emotions (anger and disgust) which had higher likelihoods in disliked samples with *Surprise flavour* (peppermint and liquorice). Facial decoding of explicit basic emotions presented the only measurement that discriminated samples according to the factor *Added sugar;* thus offering an advantage over liking ratings. Explicit facial expressions discriminated samples regarding the positive emotion joy, as well as negative emotions (sadness, fear, anger, disgust and contempt).

The results of implicit emotions add to previous literature suggesting that the measurement can be useful to study negative emotions. It is the first time that explicit basic emotions via facial decoding were measured in children. Explicit basic emotions discriminated samples more than children's liking ratings and could therefore offer an easy and engaging nonverbal method for product testing with children.

3.3 CONSUMER-BASED METHODOLOGIES FOR SENSORY CHARACTERIZATION

The application of descriptive consumer methods has already come into an application with children several times. However, methodological research to validate the results obtained is needed.

Paper 5: How children approach a CATA test influences the outcome. Insights on ticking styles from two case studies with 6–9-year old children

This paper explores how children's approach to the CATA test influences the outcome. Two case studies that illustrate suitable setups for CATA tests with children of the age group 6–9 were assessed. The children's approach to the CATA task was described with ticking style indicators based on which three ticking style groups were defined. One group ticked only a few attributes probably due to cognitive limitations, e.g. lack of reading skills, limited vocabulary or ability to focus on the task. The second group gradually increased their number of ticked attributes per sample over the test, while the third subgroup ticked a steady number of attributes throughout the test. The two latter groups are likely to represent different test strategies: one using the CATA list relatively to the sample space, and one using the CATA list in a more absolute way. Analysis regarding data validity assessed by the detection of pre-defined Design of Experiment (DoE) sample differences and the alignment to a trained panel using Quantitative Descriptive Analysis (QDA) revealed that ticking style played a crucial role. This study shows the importance of analysing "ticking style" as a validation strategy for CATA tests run with children and as a tool to gain insights into underlying test strategies.

4 DISCUSSION AND FUTURE PERSPECTIVES

4.1 CO-CREATION TO DEVELOP HEALTHY NEW FOOD FOR AND WITH CHILDREN

Previous to this thesis work, no literature explored co-creation methodology for new food product development with children. Paper 1 introduced the potential of co-creation to develop healthier food that children would enjoy and chose. Paper 2 proposed a methodological approach applicable to the early stages of new product development: ideation for healthy food concepts based on case studies in two settings, focus groups and online. Results provided first indications that children could develop concepts for healthy food in co-creation settings.

In the focus groups, the trained moderator steered the group towards the development of health-focused ideas by engaging participants in a dialogue. In the online setting where children brainstormed on their own, many ideas did not have healthiness in mind. Out of two winning ideas voted by participating children in the online setting, one was particularly unhealthy indicating that children were not so much on board for the healthy eating mission. The approaches and outcomes observed in focus group vs. online setting have similarities to current knowledge on best practices of parental feeding: the online setting was somewhat permissive, leaving all the decisions to the children, resulting in less healthy ideas, while the focus groups, where a trained moderator was present, were more authoritative, but responsive to participants by leaving them creative room to find their solutions.

For co-creation to be successful it is crucial to agree on a mutual goal to increase ownership and accountability (Ind & Coates, 2013; Van Mechelen et al., 2015). Since the health goal is imposed on participants by adults, they need to be convinced that the topic is important for them (Clark & Jill, 2004). Being too directive would result in tokenism "only pretending to listen to children's voices" (Clark & Jill, 2004). A follow-up co-creation study where healthy dairy products were prototyped with children, used a preceding session where the problem of excessive sugar content in dairy products for children was introduced (Velázquez et al., 2022). Subsequently, children were self-motivated to use as little sugar as possible. An alternative could be a film that addresses the negative consequences of obesogenic food environments to children, see e.g. Donovan (2016) in a different context.

The methodological approach in paper 2 encompassed only the early stages of new product development and the product development scenario was fictional. Future research could find real product development projects in collaboration with industry or caterers. In addition to the presented steps, an initial sensitization phase could engage children for the goal (healthy eating). Further, the scope could be expanded to the creation of real food prototypes and the testing of them as done in a follow-up study (Velázquez et al., 2022). The full process is visualized in Figure 18.

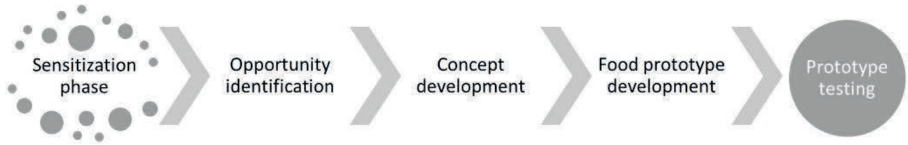

Figure 18: How a full co-creation process could look like

Experts could be included in different stages to increase the actionability of ideas. For example, chefs could help to translate initial concepts into real food prototypes. While the online setting was not satisfactory regarding engagement and healthiness of ideas, online elements could be included in a focus group or workshop settings. The food blog could for example be a starting point to explore children's food practices in the opportunity identification stage. Initial brainstorming could be performed in a crowdsourcing approach to generate many ideas quickly and suitable ideas could be refined in groups. Group brainstorming often resulted in compromises, which Van Mechelen et al. (2015) described as *group thinking*. Previous literature suggested that individual brainstorming might produce more creative (Putman & Paulus, 2009) but less detailed ideas (Schweitzer et al., 2015). Therefore, the combination of a first individual round followed up by a group brainstorming could offer an advantage.

Further research is needed to provide evidence that co-creation works and can provide added value to the industry or research projects. Concepts developed in paper 2 could be evaluated regarding actionability by R&D professionals. The follow-up study where children created prototypes for healthy dairy products resulted in a high acceptance by children who were involved in the co-creation process (Velázquez et al., 2022), but the question remains if other children who were not involved would also like them. Further, researchers from technology design have highlighted that participatory approaches should think beyond the user-friendly end product as evidence of success (Druin, 2002; Iversen & Smith, 2012; Van Mechelen et al., 2015) as participants' experiences throughout the process are important too. In the food context, co-creation can enable participants to shape their food environment by creating solutions that are meaningful to them. In the best case, children can develop more self-efficacy for healthy eating. Future research should include such criteria as evidence for co-creation approaches as well, although they might be more difficult to measure.

4.2 COMPARISON OF CLASSIC DIRECT METHODS AND NEW INDIRECT METHODS WITH PREADOLESCENTS TO STUDY THEIR RESPONSES TO PRODUCT PROPERTIES

Quantitative indirect methods are a relatively new topic in sensory and consumer science. Dual processing theory is currently a widely acknowledged model to describe decision making processes such as food choices (Jacquier et al., 2012; Rangel, 2013). It is assumed that food choices are often driven by automatic compared to more reflected decision making (Jacquier et al., 2012; Rangel, 2013), particularly in children (Köster, 2009). New indirect methods aim to assess these automatic drivers of food choices as traditional questionnaires are more representative for reflected thinking. Paper 3 assessed the Approach Avoidance Task (AAT) regarding individual differences in children's approach biases to different snack groups. The AAT is a particularly easy implicit reaction time task that has not been used with children in a food-related context so far. Paper 4 measured basic emotions via facial decoding in a product testing context. In both studies, measurements were compared to direct, questionnaire-based measurements such as liking ratings on a 7-point scale.

4.2.1 Approach Avoidance Task to measure implicit approach biases

Paper 3 suggested a food-related Approach Avoidance Task (AAT) setup with children to measure their approach biases to snacks pictures differing in calorie content and sweetness level. No significant effect of sweetness level nor calorie content was found although expected liking ratings revealed a clear preference towards the high sweetness level and high-calorie snacks.

The Approach Avoidance Task (AAT) is based on the quick classifications of images while the reaction time is measured. The application of the AAT with children resulted in a high ratio of excluded data points due to classification errors as well as outliers linked to long or short reaction times which could happen if a child is distracted from the task. The percentage of missing answers was higher than in comparable AAT studies with adults (e.g. Lender et al., 2018). The test power of reaction time tasks with children might be generally lower due to limited attention spans that hinder fast and exact responses over an extended period. Lower test power has been previously described for children in a related reaction time task, the Implicit association task (IAT) (van der Heijden et al., 2021).

Nevertheless, some interesting tendencies were observed. Children’s approach biases were significantly correlated to their expected liking ratings. Further, results suggested that children’s approach biases towards different snack groups were more dependant on their hunger state than explicit liking ratings that were more static.

Reaction time tests relate to a specific paradigm and are strongly hypothesis-driven. The elaboration of such tests requires extensive research and the presented study can only be considered as starting point. Future studies could:

- Optimize the AAT test protocol further for children (discussed in the paper)
- Explore situational aspects more systematically or otherwise eliminate such variables
- Include a food choice task with similar food groups as tested in the AAT to compare direct and indirect measurement in a relevant food choice context
- Include eating amount as additional measurement. A previous study with adolescents measuring approach bias with a related reaction time task placed implicit approach bias towards unhealthy food as a mediator

between impulsive personality traits and uncontrolled eating in adolescents (Booth et al., 2018).

4.2.2 Facial decoding to measure food-elicited basic emotions

Paper 4 suggested a procedure to perform facial decoding with children in tasting experiments and offered first insights into the applicability of such measurements for the understanding of hedonic and emotional reactions to foods. The test protocol included a video instruction to enable a standardized one sip tasting. Apart from implicit facial expressions, children were asked to explicitly indicate with their face how they felt about the tasted sample, a procedure proposed by Danner et al. (2014).

As in previous studies, implicit emotions were measured for disliked samples (Danner et al., 2014; Kostyra et al., 2016; Pedersen et al., 2021; Zeinstra et al., 2009). Therefore, the measurement of implicit basic emotions based on facial decoding could be useful to measure food-elicited disgust which is a relevant topic in the context of food neophobia and picky/fussy eating. Results suggested that implicit emotions were less sensitive than explicit measurements regarding the discrimination of disliked samples and thus did not provide additional information. However, nonverbal methods could be useful as an observational measurement in applications with younger children who cannot perform self-administered tests or also in real eating situations.

Particularly interesting was the fact, that explicit basic emotions where children were asked to show with a facial expression on how they felt about the tasted sample, were a more sensitive measurement than liking ratings. Explicit facial expressions might to a certain extent be relevant in social eating situations where facial expressions are used as a communication tool. Further, they could present an easy and fun measurement tool in computerized sensory testing with children.

4.3 EXPLORATION OF CONSUMER METHODS TO UNDERSTAND THE INFLUENCE OF PRODUCT PROPERTIES IN CHILDREN'S RESPONSES TO FOOD

The qualitative, as well as quantitative methods explored in the case studies of papers 2 to 5 all, generated insights into children's perception and preferences of product properties. As previously shown by Waddingham et al. (2018), also the creative and enabling methods used in the co-creation study (paper 2) were suitable to generate insights into children's drivers of food choice in an explorative, inductive and context-specific way not based on pre-defined product properties. Paper 3-5 explored quantitative methods based on predefined product properties and were, in this sense, more hypothesis-driven or deductive. The quantitative methods each assessed a specific aspect that is relevant in food choice: Perception (CATA) – implicit and explicit basic emotions (Facial decoding) – implicit approach bias (AAT).

In methodological research, it is important to assess the data quality obtained. For the qualitative co-creation study, it was not a straightforward task due to its exploratory nature without a right or wrong outcome. Thematic analysis of the data was performed to display the characteristics of insights obtained. Further, feedback on engagement by participants was obtained. For the quantitative methods, the discrimination of pre-defined sample differences served as an indication. Further, measurements were compared to more established, validated measurements. In the case of indirect methods (paper 3 and 4) to direct questionnaire-based methods, such as liking ratings on a 7-point scale. In the CATA method (paper 5) to a Quantitative Descriptive Analysis (QDA) by a trained profile panel which is the golden standard for descriptive analysis. In all three cases, the new measurements were not necessarily expected to reflect the measurements by more established methods. Indirect measurements are thought to measure implicit aspects and direct measurements are more representative for explicit aspects, therefore the measurements could diverge. And the sensory perception of children does not necessarily have to correspond to the sensory perception of an adult trained profile panel. However, in all cases, measurements were related.

Paper 5 further investigated how the usage of the CATA method influenced the perceptual space. Three different ticking style groups were defined based on the data of the two case studies included and one group's (the few tickers) performance regarding sample discrimination and similarity to the trained profile configuration was inferior. This group consisted mainly of very young children (6 and 7 years old) although the age effect was not significant. The findings highlighted, that the CATA method was more suitable for older children (8 to 9 y. o.) but that individual differences in cognitive development within age group occurred.

While hypothesis-driven sensory lab tests are often a bit tedious through their repetitive nature with minimal information on test aim and outcome, children seemed to enjoy the creative and enabling methods in focus group settings. Engagement is a topic that has often been overlooked in methodological development so far. Particularly with children, engagement is important to capture attention and assure ethical standards that children's involvement in sensory and consumer studies follows their free will. Recently, an engagement questionnaire for sensory and consumer methodology assessment has been established for adults (Hannum et al., 2021; Hannum & Simons, 2020). In paper 2, focus groups and online settings were compared regarding participant's engagement with a short questionnaire that reflected different aspects of their flow state experience during their participation. It was a valuable insight and feedback to the online setting where researchers could not observe the process and highlighted that the online setting required optimization. Future methodological assessments could have such aspects in mind as well.

A particular question that stuck with me when writing about the necessity of food tailored to children's preferences is that children should be encouraged to expand what they like as their diets are often somewhat limited due to a period of increased food neophobia at an early age. Köster and Mojet (2018) highlighted, that consumer tests need to take into account that preferences evolve. Most sensory and consumer studies assess liking or preference at one specific time point which might create oversimplistic solutions based on what consumers are already familiar with (Köster & Mojet, 2007, 2016). However, it might not satisfy them in the long run and as mentioned it is important to encourage children to expand their taste palate. The question remains how to establish consumer test methodologies that could estimate children's long term product acceptance. Repeated testing procedures that are quite time-intensive have been suggested (Morizet et al., 2022). Köster and Mojet (2018) indicated that motivational arousal might lead to future tasting. Could the measurement of emotions or also implicit biases serve as an indication of a future tasting? Taste learning seems individual and heavily dependant on context. Hwang et al. (2020) discussed the design concept MAYA (most advanced yet acceptable) as a relevant food design principle for children, suggesting only incremental changes, always including something already familiar. Could co-creation approaches with children be useful, so children can inform product developers how much novelty is acceptable?

5 CONCLUSIONS

The presented thesis aimed to establish research-based knowledge on suitable consumer insight and food testing methodologies with children. The targeted age group of this thesis were preadolescents who are becoming more autonomous in their food choices, so the study of their self-directed food choices is highly relevant.

The thesis addressed three topics: 1) Co-creation as a way to engage children actively in new product development of healthy food. 2) Indirect methods in comparison to classic direct, questionnaire-based methods. 3) The assessment of the sensory characterisation method Check-all-that-apply with children.

The thesis explored, for the first time, co-creation with preadolescents in different settings (online and in focus groups), as new approach to food product development with and for children. Results of the developed approaches provided first indications that preadolescents could develop concepts for healthy food in co-creation settings. Focus groups and online platforms produced distinct insights, each which their advantages and opportunities. The feedback and observations from the study, particularly in the creative focus group setting, implied that the creative approach was highly engaging for participants.

Two novel indirect methods were explored, the Approach Avoidance Task (AAT) as particularly easy implicit reaction time task from psychology and facial decoding representing a quantitative observational biometrics method.

The Approach avoidance task (AAT) was investigated in a food related context for the first time to study children's automatic approach tendencies. The set up worked successfully but the acquired data contained a high amount of missing data resulting in low test power, which entailed statistical challenges. Children displayed a significant positive approach bias towards snack (food) pictures in general but we did not find significant differences in approach bias towards snack pictures with different levels of sweetness and calorie content. Results suggested a weak correlation to expected liking ratings. There were some common and some distinct patterns between the implicit and explicit results, around half of the children showed expected linking responses in line with their implicit bias, while other children had distinct or even opposite patterns, suggesting that measurements via AAT and liking ratings may be representing different driving forces behind food behaviour. Further, children's approach biases to different snack groups were more strongly linked to their hunger state than expected liking ratings suggesting a potential relevance for situational food choices.

Using facial decoding children's implicit and explicit basic emotions elicited by tasting were measured and compared to liking ratings. A procedure to perform facial decoding with children in tasting experiments was established, which was not done before in literature. The test protocol included a video instruction to enable a standardized one sip tasting of the assessed chocolate milk samples. Apart from implicit facial expressions, children were asked to explicitly indicate with their face how they felt about the tasted sample. The measurement of explicit facial expressions was more sensitive regarding sample discrimination than liking ratings. It could be an easy and fun measurement tool in computerized sensory testing with children. In line with previous studies on adults, implicit facial decoding with children discriminated samples according to negative emotions (anger and disgust). Therefore, the measurement of implicit basic emotions based on facial decoding could be useful to measure food-elicited disgust which is a relevant topic in the context of food neophobia and picky/fussy eating with children.

The application of the CATA as easy descriptive consumer method has come into application in previous studies with children. The novel aspect of the presented thesis results from the study of data validity, as assessed by the detection of pre-defined Design of Experiment (DoE) sample differences and the alignment to a trained panel using Quantitative Descriptive Analysis (QDA). Further, children's approach to the CATA task was studied by defining ticking style indicators: number of ticks, standard deviation of number of ticks per sample, and number of different attributes used in the test. Three groups of children were unveiled, and differences among groups may reflect different cognitive development levels and test strategies. The findings highlighted, that the CATA method was more suitable for older children of the study (8 to 9 vs. 6 to 7 y. o.) but that individual differences in cognitive development within age group occurred. Results showed the importance of analysing “ticking style” as a validation strategy for CATA tests run with children and as a tool to gain insights into underlying test strategies.

This PhD thesis established novel methodological approaches with children, that can be applied by the food industry, at different stages of the development of healthy food products - from idea generation to product validation. It also produced research-based knowledge for better understanding children’s perception of food and food testing procedures, including age-specific recommendations for collecting data and opening new opportunities for further method development.

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7 PAPERS

Paper 1 Children as food designers: The potential of co-creation to make the healthy choice the preferred one

Paper 2 Listening to children voices in early stages of new product development through co-creation – creative focus group and online platform

Paper 3 Children's sweet tooth: explicit ratings vs. implicit bias measured by the Approach avoidance task (AAT)

Paper 4 Capturing food-elicited emotions: facial decoding of children's implicit and explicit responses to tasted samples

Paper 5 How children approach a CATA test influences the outcome. Insights on ticking styles from two case studies with 6–9-year old children

Paper 1

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Children as food designers: The potential of co-creation to make the healthy choice the preferred one

ABSTRACT

According to the WHO, childhood obesity is one of the most serious public health challenges of the twenty-first century. In this context, finding ways to make the healthier food choices the preferred ones can be a valuable contribution to solving this multifaceted problem. Sensory and consumer science offers a wide range of tools that can support the development of healthy and well-accepted food alternatives. In traditional sensory and consumer science, children would be involved in the product development process either as testers or informants. However, in our opinion, it would be valuable to extend their role to co-creators or co-designers, an approach already more established in the field of innovation and design, where children actively participate in the idea generation and development of healthy food that they will like and choose. Our own experience has shown that involving

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innovation
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children in the idea-generation step for healthy food can be highly motivating and stimulating for them. In this opinion article, we discuss why it is important to include children actively as a relevant consumer segment in product development and suggest a process and methods that could be valuable for brainstorming about food ideas with children.

Nearly one in five children is overweight or obese world-wide and the numbers are growing (WHO 2018). Regulation measures recommended by the WHO, such as restricting promotional marketing of unhealthy food to children, taxing sugar-sweetened beverages and front-of-pack labelling, are being implemented around the globe and are hopefully going to accelerate the development of healthy food alternatives in the coming years.

It is important to involve children in new product development in order to make sure that healthy alternatives meet children's needs. Healthiness alone will not convince children, who place a high focus on immediate pleasure opposed to long-term health goals, because their brain area linked to self-regulation is still developing (Lowe et al. 2020). Further, it is well known that children's preferences can be different from those of adults. Children display, for example, a preference for a higher sweetness level than adults, a stronger disliking of bitter food (Forestell and Mennella 2015) and many times, reject certain textures (Laureati et al. 2020; Dovey et al. 2008). Also, extrinsic product properties, such as packaging design (Pires and Agante 2011) and the arrangement of dishes on a plate (Zampollo et al. 2012), play a crucial role in their food choice. A good product development should study and respect children's preference patterns while finding mechanisms to spark children's curiosity towards a broader food palate, the so-called acquired tastes.

Almost 30 years ago, the initiative 'Cities of Children' was started to consider children as point of reference for urban development in order to transform the way we use cities (Tonucci 2019; Tonucci and Rissotto 2001). The initiative was started in Fano, Italy and has now been applied in more than 200 cities world-wide. In these cities, children have been actively involved in 'Children's Councils' as well as in the design of architecture and urban planning projects (Tonucci 2019; Tonucci and Rissotto 2001). In our opinion, this approach, taking children as 'sensitive indicators', could serve as role model to transform the way we eat which is today heavily focused on adults' preferences and needs. Maybe it is time to create the future of eating with children.

Interesting to note is that Tonucci and colleges are not in favour of compartmentalizing playgrounds to designated areas in a city, stating that designed playgrounds do not offer nearly as much excitement and spontaneous learning as the mingling with the adult world. It is worth evaluating if this applies to the food domain where the sector specifically targeted at children is growing. A more integrative approach where children are simply regarded as a relevant and demanding consumer segment for food consumed by everyone might be a valuable second path to consider. In their review about picky eating and food neophobia, Dovey et al. (2008) describe that a child might learn to accept food through observing significant others (the more the better) eating the same food. Studies on baby-led weaning suggest that weaning infants with family food instead of purées is possible and may lead to a better self-regulation of energy intake (Cameron et al. 2012). The Hindu ceremony Annaprashan is an interesting tradition to initiate an infant into the family's eating tradition; the ceremony celebrates the infant's first solid food eaten by presenting a variety of popular dishes to taste (Srividya 2018).

Ideally, children's needs and preferences are integrated in family meals as well as the 'outside food world', such as food retail and restaurants. For a child-centred product development we regard the participatory and interactive co-creation approach as particularly promising. Involving consumers in the early creative stage of product development has a long history in the design and innovation disciplines (Sanders and Stappers 2008; Von Hippel 1986) and has recently gained attention in food product development and consumer research to increase the market success of new products (Busse and Siebert 2018; Grunert et al. 2008; Schifferstein 2015). Co-creation extends the traditional more passive involvement of consumers as users, testers or informants to a more active role by including them in the creative idea generation stage of new product development as partners (Druin 2002; Sanders and Stappers 2008). This calls for new methods and approaches to brainstorm with consumers about food; a publication by Banovic et al. (2016) offers insights, focusing on adults. Co-creating food with children has the potential of generating ideas that adult product developers could not develop themselves. At the same time participatory co-creation initiatives can empower participating children to find their own way to pleasurable healthy eating thus laying the foundation for change.

Ind and Coates (2013) argue that basically everyone can co-create, as long as the motivation is high, and the right conditions and processes exist. According to them, the main prerequisites are knowledge and motivation. The co-creation goal as well as the setup should appeal to intrinsic motivation to participate. The goal of the co-creation project has to mutually benefit the organizer of the project as well as the participating children (Ind and Coates 2013). Further, gamification elements, e.g., described in Chou (2015), can enhance task absorption during the co-creation session, which contributes to a pleasurable participation experience.

In our co-creation study, we focused on the first stage of product development – idea generation – with child participants who were between nine to twelve years old, an age group that is starting to be more autonomous in making food choices. We defined three steps: *Show and Tell, Reflect and Create*, applied via two setups: a focus group setting (three focus groups of six to eight participants) and an interactive online platform (with one school class of 52 children). The first two steps laid the foundation for the last creative step by generating group knowledge about the current eating situation.

(1) *Show and Tell*: Photovoice and photo elicitation are methods from participatory action research that enable children and youth to record and reflect on their realities. The methods have been used in previous research about food habits of children and youth by Findholt et al. (2011) and Martin Romero and Francis (2020). In our study children took photos of snacks they ate and then either described their snacks in a guessing game or posted them on an interactive food blog with a description.

(2) *Reflect*: Projective sorting or mapping is a frequently used method in sensory and consumer science to learn about the perception of consumers (Ares and Varela 2018). Consumers structure images or other stimuli based on perceived similarity and optionally describe their groups. In our study, children sorted the different snack items collected in the photovoice task based on liking, healthiness and eating occasion helping them to 'make sense' of their current food habits.

(3) *Create*: The newspaper article brainstorming technique described in Gray et al. (2010) takes away the fear of failure as it pretends that the fantastic idea has already been created and is worth being reported by a newspaper. In our study, children invented a new healthy snack idea with the instruction to think about what snack they would like to be able to find at home or buy in a store that did not exist yet. They then brought their idea to paper in the form of a newspaper article. The template for the article was composed of a headline with the product name. A text field where the product was described, an image field for a drawing of the prototype as well as two quote bubbles for comments of what imaginary consumers would say about the product as displayed in Figure 1.

Our experience in the focus group showed that the creative task was highly engaging for the participating children. Initial shyness was overcome, and high collaboration was reached in most groups. Promising ideas were developed offering insights in children's needs and preferences and how to increase product appeal for them. A particular aspect in working with food is that it is not easy to imagine and talk about taste and texture. Instead of *Show and Tell*, *Taste and Tell* might have been a more appropriate approach to dig deeper into sensory properties beyond visual aspects, such as a tasting buffet. Furthermore, not all ideas were healthy and applicable. The initial ideas should be followed up and narrowed down with a critical discussion about healthiness and applicability. After the idea generation, next steps in the creation process could include co-cooking sessions with professional chefs that could elaborate on initial ideas for which Isaku and Iba (2015) offer good advice.

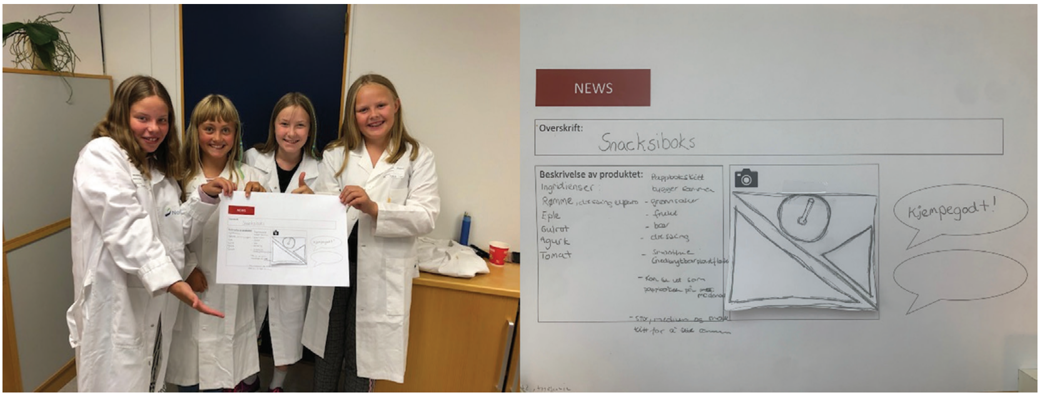

Figure 1: Pilot focus group with their idea 'Snaksibox', a modular setup allowing the consumer to choose vegetables, fruits and dip based on individual preferences.

We hope to publish detailed accounts of our brainstorming study soon and would like to encourage product developers as well as chefs to further include children's needs and ideas for healthy eating. The intersection of consumer science, innovation and design offers the tools for human centric approaches to make people's, and particularly children's, lives better and healthier. Future research could draw on the knowledge from these disciplines for new co-creation experiences with the aim of understanding children's needs, empowering them to eat healthy and developing healthy products for and with children.

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PAPER 2

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Listening to children voices in early stages of new product development through co-creation – creative focus group and online platform

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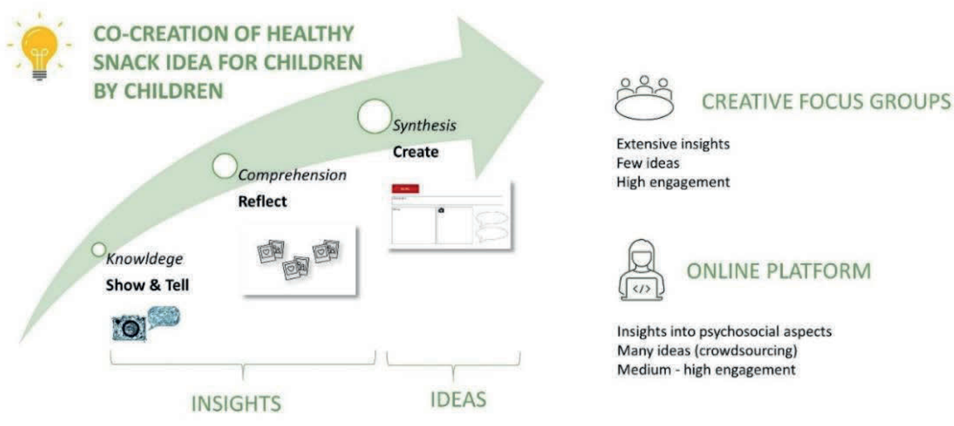
Abstract

To tackle current nutritional issues like obesity, it could be valuable to involve children in the development of healthy food products that they will actively chose and enjoy. The aims of the present study were to explore a methodology for early-stage idea generation through co-creation, for the development of healthy snacks with pre-adolescents. We compared two settings, creative focus groups (CFG) and an online community (ONL). Three steps were defined to allow the gradual exploration of the topic and mutual learning throughout the process: (1) *Show &Tell*: photo taking and -elicitation, commonly used in participatory research, to understand what children ate; (2) *Reflect*: a sorting task of the pictures to discuss and reflect on snacking practices (3) *Create*: an idea generation step, in which a newspaper article describing an idea for a new healthy snack was created. To increase engagement and creativity, gamification strategies were used. Our results demonstrated that children (preadolescents) can create new food product ideas, with the proposed process, using enabling and creative techniques. In the CFG the trained moderator could steer the group to the co-creation goal. The setting facilitated teamwork and group learning, collaborative ideas considering preferences of peers and produced a few detailed and mostly actionable ideas. In the ONL less control over the process was possible. The setting produced many ideas varying in the degree of detail and actionability focusing on individual preferences. The ONL can be regarded as a crowdsourcing approach. The feedback and observations from our study, particularly in the CFG setting, implied that the creative approach was highly engaging for participants. Further research is necessary to assess the potential of initial ideas.



Key-words: Co-creation, children, healthy food, idea generation, online community, focus group

1. Introduction

The rising prevalence of childhood overweight and obesity worldwide calls for healthy food options that children will actively choose. For a successful new product development, it is beneficial to involve children to a high degree, to tailor products to their preferences and needs. Also, future food system scenarios indicate the need for substantial shifts in our diets (Højlund et al., 2020; Willett et al., 2019). The involvement of children as next generation of eaters in future food scenarios might therefore be highly relevant.

A paradigm shift in new product development has brought forward the concept of co-creation and open innovation where stakeholders such as consumers participate as active partners, often with a focus on idea generation (Baldwin & Hippel, 2010; Ind & Coates, 2013). The active engagement of children could ensure that children's voices are included (Druin, 2002) in the creation of healthier food environments. Currently, there is limited methodological research on how to involve consumers co-creation activities for food idea generation, particularly children. In other fields, children have been successfully involved as co-designers of apps and educational software (Alhumaidan et al., 2018; Guha et al., 2004; Kelly et al., 2006; TaxÉn et al., 2001; Thabrew et al., 2018).

Compared to younger children, preadolescents (appr. 9 to 12 y.o.) possess an advanced nutritional knowledge and can access to their underlying drivers of liking to a higher degree (Zeinstra et al., 2007). This age group transits from family driven to more autonomous food choices (Hill, 2002; Warren et al., 2008). Drawing on self-determination theory (Cormack et al., 2020; Gillison et al., 2019), a well designed co-creation initiative could potentially empower participating preadolescents to find their own way to pleasurable healthy eating while creating healthy products and meals that "speak" to children.

Ind and Coates (2013) stressed the need to engage co-creation participants in a reciprocally useful way, considering also the enjoyment and meaning for the participants. While a mutually beneficial co-creation goal is important, gamification (e.g. Chou, 2015) can also enhance the immersion in tasks and their enjoyment. For applications with children, the skills and interest of the involved age group need to be carefully considered, tailoring tasks and settings to their optimal experience point, between boredom and anxiety, which Csikszentmihalyi (1990) defined as flow.

Focus group settings are particularily suitable to facilitate collaboration and discussion in brainstorming activities, e.g. used by Banovic et al. (2016). Meanwhile, interactive online platforms might be an alternative to interact with the digitalized generation. Social media platforms encourage users to create and share content that reflects their opinions and ideas, offering new opportunities such as co-creation through crowdsourcing (Hoyer et al., 2010; Martini et al., 2014; Olsen & Christensen, 2015). Children might feel more free to articulate their opinions online than in focus groups, where they typically come to unfamiliar research facilities, which can be intimidating.

The aims of this research were:

i) To explore a methodology for early stage idea generation with pre-adolescents in co-creation activities around healthy food

ii) To compare the methodology for the development of healthy snack ideas with pre-adolescents in two settings, creative focus group and online community

2. Materials and Methods

2.1. Methodological framework

The co-creation goal in the study was to develop an idea for a healthy snack[2]. Snacking plays an important role in preadolescents' diets and has the potential to influence diet both positively and negatively (Dunford & Popkin, 2018; Loth et al., 2020; Taillie et al., 2015).

A multiple method setup with three stages was used: *Show & Tell, Reflect, Create.* The three stages were designed to allow the gradual exploration of the topic and mutual learning throughout the process. According to Bloom's taxonomy, learning evolves from concrete to abstract with the three main stages: knowledge, comprehension and synthesis (Krathwohl, 2002). In the revised taxonomy by Krathwohl (2002), creating requires therefore remembering and understanding as well as analysing and evaluating as prerequisite.

- In order to remember and understand, *Show & Tell* was defined as first stage, encompassing a photovoice exercise, i.e. photo taking and -elicitation. The visual picture taking approach is an enabling technique often used to give children and youth a voice (photovoice), e.g. in obesity prevention (Darbyshire et al., 2005; Findholt et al., 2011; Martin Romero & Francis, 2020; Woolford et al., 2012) or weight management programs (Woolford et al., 2012). In the case studies, children took photos of their snacks and described them to each other.
- The next stage, *Reflect*, aimed to analyse and evaluate current snacking practices with a projective sorting task. Sorting tasks are simple undirected, unstructured tasks frequently applied in focus group settings (Colucci, 2007), with the goal of eliciting participant's underlying perceptions and motives, which could be hidden by factors such as social desirability or lack of introspection (Mesías & Escribano, 2018). Sorting techniques, such as mind mapping, are also used as basis for brainstorming activities, helping participants to gain an overview and "make sense" of a topic (Gray et al., 2010).
- The last stage, *Create*, had the goal to come up with an idea for a new healthy snack. In order to create a noncritical framework which is known to enhance creativity (Osborn, 1953), no further specifications for degree of healthiness or novelty were given. A newspaper article brainstorming technique adapted from Gray et al. (2010) was used. This technique pretends that the idea is already created and is worth being reported by a newspaper, thus lowering the fear of not being able to come up with a relevant idea. The template for the article consisted of different aspects: headline, text field, image field and two speaking bubbles (Figure 1).

[2] While the term "healthy snack" or "snack" is used throughout this publication the term "mellommåltid" (translated as "in between meals") was used in the study because snack implies unhealthiness in Norway (e.g. crisps, candy). "Mellommåltid" can be almost a real meal due to the eating structure in Norway. In most schools, children eat a cold lunch brought from home during a short break at around 11. When they come home at around 2 PM, they are hungry, so this is typically the time where they eat a "mellommåltid" which can be cold or a simple cooked meal, usually prepared by themselves. Therefore, simple hot dishes like pasta, are included as well.

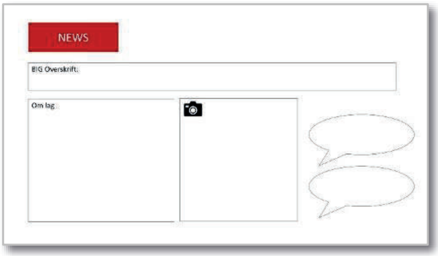


Figure 1. Photographs of the three tasks included in the Creative focus group (CFG) and Online community (ONL)

The experience itself of participation in co-creation initiatives is likely to influence the outcome and is crucial for its success (Ind & Coates, 2013). Therefore, participants were asked for an anonymous feedback at the end of the study, including interest, enjoyment, concentration, immersion, challenge, skills, importance, and work vs play feelings. The wording of the questions is presented in Appendix 1.

2.2 Procedure

The multiple method process was implemented in two settings: creative focus groups (CFG) and an online community (ONL) (Table 1 and supplementary material, Figure 1). Both test settings were registered with the Norwegian data protection office (Nr. 347529 and 957208). Participants were recruited as convenience samples, from after-school activities or school classes. No specific selection of participants besides age group was intended. We assumed that everyone can be part of a co-creation team (Ind & Coates, 2013). Children and their parents received a one-page information letter understandable by children, a flyer explaining the project (Edulia, H2020 MSCA-ITN) and a form to be signed for parental consent and children assent. At the beginning of the study, children were informed that they could leave the study at any time without any negative consequences. A small monetary incentive was paid to the sports club / school class as token of appreciation for their participation.

Table 1. Implementation of the multiple-method process in the two settings: creative focus groups (CFG) and an online community (ONL).

	CFG 3 focus groups of N=6-7 9-12 y.o. 1.5 h Trained moderator present	**ONL** 1 online platform N=52 10-11 y.o. 3 weeks Self-administered (help page and support on request by teacher)
Show & Tell	Prior to the focus group, participants were asked to submit three photos of snacks that they typically eat. The focus group started with a "Taboo", guessing game: the participant received a card, with their snack picture and three to four words which comprised obvious descriptions that they could not utilize ("forbidden words"). They had to describe, during 45 seconds, one to two of their own snack photos, based on sensory characteristics and other properties, the rest of the group had to guess the food.	Participants created a food blog by uploading pictures of their own snacks they ate after school, and describing the snack in the post. Commenting and liking of each other's posts was possible (social media setting type).

Reflect	Individual sorting of 27 images of snacks, selected based on *Show & Tell* and prior pilot tests. Followed by group discussion about participants' snacking habits, health perception and barriers and facilitators for choosing healthy snacks, based on commonalities and differences in the maps.	On-screen individual sorting (same images as in CFG) with a mandatory description of the groups formed. Data was collected in the software Eyequestion. A feedback of the consensus configuration (whole group) was uploaded to the online community once all children had performed the task.
Create	Brainstorming in two groups of 3-4 children with newspaper article format. Presentation of idea generated to the other group followed by a short discussion about the feasibility of the invention.	Individual brainstorming with newspaper article format (same as in FG). Uploading of idea on ONL platform. Voting on the best liked idea in two subgroups of the class was performed to select two winners.

2.2.1. *Creative focus groups (CFG)*

Three groups of seven to eight children were recruited from two sport teams in the Akershus region in Norway, as most Norwegian children participate in some sort of after-school sport activity. Involvement of sport teams had the advantage that participants knew each other, which facilitated group discussion and collaboration within the relatively short time of 1.5 hours. Three groups with different characteristics were recruited. Group 1 consisted of 7 girls between 9 and 10 years old from a swimming team, whereas Group 2 involved a mixed gender group, composed of 4 girls and 3 boys that were between 9 and 12 years old, from the same swimming team. The last group (3) consisted of 7 boys between 11 and 12 years old recruited from a soccer team.

Participants were set up in the context of being product developers at Nofima where the study was conducted, inventing new products. As prop, lab coats were distributed. The focus group guide was pilot tested with two groups. Substantial adaptations were made after the first pilot regarding context and brainstorming technique. A trained focus group moderator led all the groups. Two researchers assisted, one of them moderated the *Create* part where the focus groups were split in two subgroups. The implementation of the multiple method process is described in Table 1. The groups were filmed and recorded throughout. The feedback of participants' experience was collected orally as well as with the anonymous feedback questionnaire at the end of each focus group.

2.2.2. *Online platform (ONL)*

A 5th grade class (10-11 year old children), N=52, from a town in the Akershus region in Norway, participated in the study as part of their Food and Health classes over several weeks.

The interface called "Din Matidé" ("Your Food Idea" in English) was set up on the software platform Padlet Backpack. The format was like a pinboard, from which participants could access the tasks via links (Figure 2). An information text box was included to instruct children what to do, as well as each deadline. The three tasks were posted sequentially on the pinboard. Finished tasks were moved below, so participants always saw the current task on top. Each task was started during the class period and continued from home until the next class. Some permanently visible content was included on screen: "fair play rules", link to "help page" where questions could be posted to researchers, a link to the Edulia project page as well as a Fact or Fiction game related to sensory science and taste perception which participants could play during waiting times. An anonymous setting was chosen for the posts, to lower the threshold of "daring to post" and avoid bias in the judgements of the other participants. However, comments were not anonymized, so participant got ownership and responsibility of their own judgements of the posts of others. The online platform was initially explained by the researchers to all children in a classroom, using a screen to show the platform functioning. During the study the teacher supported the children. The implementation of the multiple method process in the ONL setting is described in Table 1. At the end of the study, participants completed the anonymous feedback questionnaire (detailed in Appendix 1) and a ranking of tasks based on enjoyment. Researchers joined students to determine the winning ideas and give a small price (miracle berries that alter sour taste to sweet taste previously used in taste education (Lipatova & Campolattaro, 2016)) and present the results of the Fact or Fiction game.

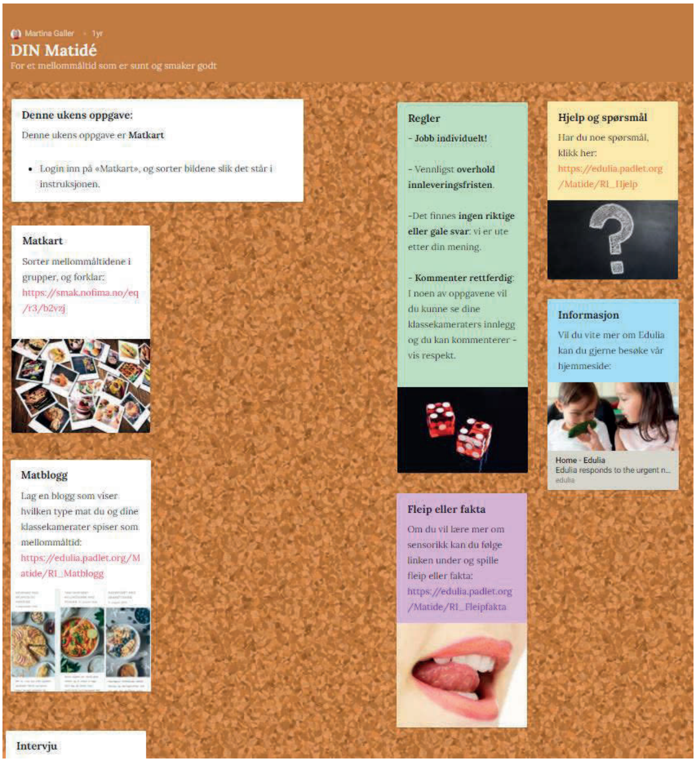


Figure 2. Screen capture of the main page of the ONL study "Din Matidé" (Your Food idea)

Data analysis

The CFGs were transcribed. The outputs from each task, photos and descriptions (*Show & Tell*), descriptions of snack groups (*Reflect,* only ONL), the text and drawings of newspaper article (*Create*) as well as the transcript of the CFGs were considered for the analysis. Data was qualitatively analysed using inductive thematic analysis to gain an overview of the topics addressed. The material was coded with paper and pen and categorized by the first author of this paper and discussed with the co-authors to gain multiple perspectives on the analysis.

Some quantitative evaluations and data presentations are also included. The number of children showing pictures of different types of snacks in the *Show & Tell* task was calculated. For the *Reflect* task of the ONL setting, a group configuration was calculated based on the individual sorting configurations using DISTATIS (Abdi et al., 2007). Children's descriptions were analysed using inductive coding and the identified themes were projected by linear regression with the first two components of the product configuration. Only themes used by more than one participant were considered.

The anonymous feedback questionnaire was evaluated by calculating averages for the rating-based questions and frequency for the multiple-choice question. For the ONL setting, ranking of task enjoyment is also presented.

3. Results

3.1. Show & Tell

Creative focus group

Most participants (20 out of 22) sent one to three pictures of snacks prior to the focus group, as requested. Most photos showed the snack on a plate or in the original packaging (Figure 3).

The description of the photos in the guessing game “Taboo” served as ice breaker to the focus group, as well as a starting point to explore participants' perception of their own snacking habits. The descriptions in the "Taboo” game were quite elaborate regarding sensory descriptions but focused mainly on the visual and textural modalities (Table 2). Taste and flavour attributes were used more scarcely. When the moderator asked about the taste and flavour participants were often in lack of words, e.g. saying that it tastes tasty.

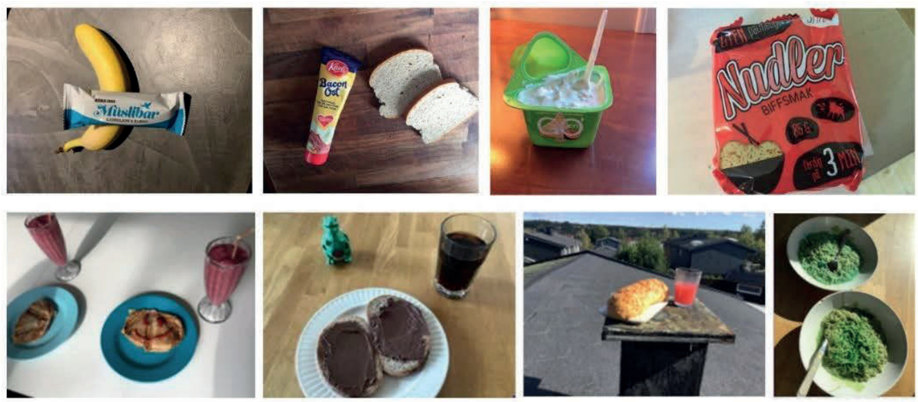


Figure 3. Examples of the photos uploaded in the *Show & Tell* task in the CFG (top row), and ONL (bottom row) setting.

Online platform

In the food blog, 47 out of 52 participants made from 1 to 17 posts, resulting in 175 posts. Social media seemed to have influenced the selection, presentation and description of the snacks (Table 2). As exemplified in Figure 2, many children depicted the snack itself as well as the setting in an original way. Pictures of non-standard snacks for the Norwegian context were frequent, e.g. green coloured pasta, mandarin juice or pancakes with coconut milk. Also, changes in standard recipes to make foods healthier or tastier were mentioned in the posts, e.g. healthy pancakes. Compared to the focus group, more unhealthy snacks and sandwiches were mentioned in the food blog (e.g. desserts were included 11% of pictures), whereas fruits were less frequent (Table 2). In addition, a higher percentage of snacks involved cooking or baking: 32% of the dishes in the ONL vs. 14% in the CFG. In some cases, preparation steps were documented in multiple posts. Whole meals including drinks, instead of single foods, were more frequently depicted (Figure 3).

Matching the social media setting, the pictures served as the main communication tool. As shown in Table 2, the text used to described the snacks was short and often accompanied or replaced with emojis depicting ingredients or hedonic and emotional associations (e.g. hearts and happy smileys), as well as hashtags (e.g. #mellommåltid, #yum, #boring). Descriptions of how snacks were prepared were frequently included.

Discussion and liking of the posts between peers were lively, which likely increased engagement and, consequently, the number of posts. The social media setting also enabled peer influences on food choices. At times, the same snack was posted by different participants. In two posts this was explicitly pointed out: *"I am a copycat", "the same pancakes as (name of peer)".* A girl mentioned at the end of the study that she was inspired to try new snacks that her classmates had posted.

Table 2. Snacks depicted in the pictures sent by more than 5% of children in the *Show and Tell* task in the creative focus groups (CFG) and an online community (ONL) settings. The number of children who sent pictures featuring each type of snack and examples of the descriptions are shown.

	Number of children	**Snack in photo (Show)**	**Descriptions of snack (Tell)** mentioned ingredients / components of the snack excluded, only a selection of used emojis displayed for ONL
CFG, 58 photos	12	Fruit	Healthy, Banana: yellow, long, looks a bit like a half moon, soft, curved, can turn brown if it's old, unique flavor, before exercise, healthy, wide range of usage (also baking), Apple: green or red, something white inside, stem on top, round, a bit hard, but also a bit soft if it falls on the ground, a bit juicy, some are dry and some are juicy, a bit sweet, tastes a bit green, tasty, very good
	10	Flavored yoghurt	very soft so you can swallow it at once, little thicker than water, liquid, viscose, white with black spots (Vanilla), for breakfast, eat it with a spoon
	10	Granola bar	contains chocolate and grains but you cannot feel it (grains), tasty, after exercise
	8	Sandwich	round, squared, soft, hard (crisp bread), has holes (Polar bread: special type of Norwegian bread), red, taste like fish (mackerel in tomato), have a lot in my place (spreadable cheese and bacon)
	8	Cereal	dry if you don't add milk, very small (oats)
	5	Instant noodles	Red, squared (packaging), chew without breaking teeth, looks like braided into each other (dried noodles), can be soft and hard, tastes like chicken and beef, tasty, boiling required, eat it with spoon or fork
	4	Vegetable	Carrot: orange, little hard, a bit long, can be a bit thick
ONL, 175 photos	54	Sandwich	It tasted very good, home-made snack (mellommåltid), smiley😊, for training, this is what I ate yesterday #mellommåltid, good for me and my little brother
	19	Dessert-like (cookies, ice cream, cake)	mmmh 😋, 😛, extremely good, 👍, 👌, home-made, from Oslo, a small cookie on the side, I felt better after, little snack, 🤣
	19	Milk and chocolate milk	Ultimoooooooo (chocolate milk brand), my breakfast #yummy It was so good ❤️
	15	Fruit	yummy, sour but good 😁, #boring, 🥝
	15	Juice	Fresh, home-made, breakfast, (ginger juice) refreshes you
	11	Pasta	pasta is good, #yummy, #goodfood, a bit late, but here is my snack from Friday 🥰❤️💚💙💜💜

	11	Pancake	tastes very good, the exquisite, 👌👌👌, can it get any better, a little comfort must be allowed, healthy pancakes, not my usual snack, but it was good 😊, like (name of peer) his pancake, now it is finally finished (referring to the cooking process) 🥞🍽😋, home-made
	10	Vegetable	little, red but also very good (cherry tomatoes), from the garden, 🥔
	9	Smoothie	yummy

3.2. Reflect

Creative focus group

After the individual sorting, the moderator asked participants to describe the groups they had made. The emerging topics steered the discussion and led the path to the last, creative step. The following topics were addressed: 1) healthiness is nuanced within food group, 2) convenience and availability of different foods at home and on the go, 3) preferences for hot food and fruits, 4) cooking skills as well as time were identified as limiting factors to eat hot food, 5) importance of healthy snacking in the context of sport.

Online platform

In the online setting, the sorting task in the *Reflect* part enabled participants to have an overview of common snacks. However, it did not allow a group discussion. A consensus configuration obtained from the individual sorting tasks revealed three main groups in the first two dimensions: fruits and vegetables described as healthy, simple and snack (*mellommåltid*), sandwiches described as breakfast and yuck as well as hot food described as warm, yummy and dinner (Figure 4).

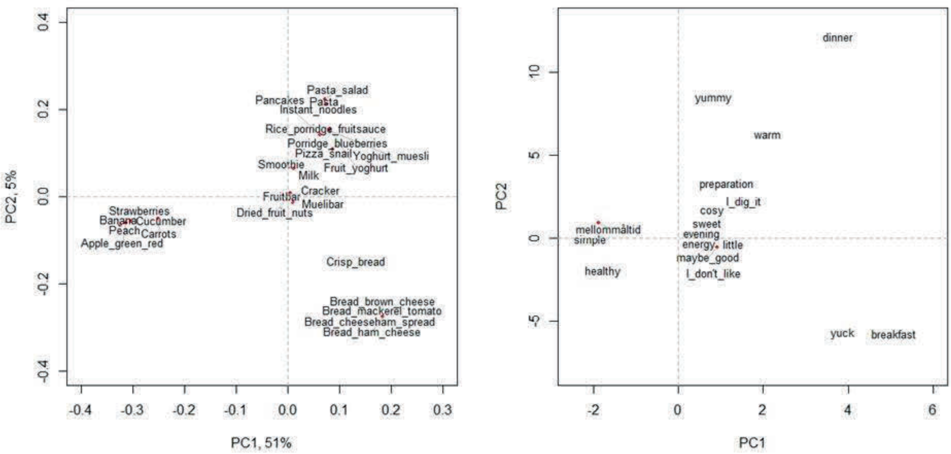


Figure 4. Consensus configuration of 26 snack images obtained from the individual responses of 46 participants in the sorting task performed in the ONL (left). Themes other than food category mentioned by at least two participants were projected (right).

3.3. Create

The newspaper template contained different fields (headline, text, image and quotes) and it was left free to the participants to use it as they wanted. Many wrote the snack name in the headline, specified the ingredients and / or sensory attributes in the main text field, drew a prototype in the image field and wrote what others would say about their invention (projective approach) as well as slogan-like texts like those one could find in a commercial in the speaking bubbles. In the focus group setting, the transcription of the discussions offered additional insights into the creative process.

Creative focus groups

The product ideas focused on the two snack groups: Easy hot food ("Naminam burger", "Heart-warming pasta" and "Big toast") and fruit snacks ("NJ2 Fruit salad", "Epan", "Graft"). The newspaper articles of the groups offered ideas for product formulation, marketing, and branding (Table 3).

Product formulation: Dinner-like snacks were better-for-you versions by including healthier ingredients, such as vegetables, whole wheat, and seeds. The heart-warming pasta had the aim of tricking children to eat healthier by hiding the healthy vegetables within the pasta: *"And then parents can lure their children to eat vegetables"*. The group further thought of a new shape, (heart shaped) that can be easily eaten with a spoon. Two groups thought of a bigger than normal version, maybe inspired by fast food commercials: "Big toast" and "Naminam burger". The "Naminam burger" was composed of ingredients from ethnic cuisine, sushi, and tikka masala.

Branding and marketing: Many of the product names were creative and potentially appealing to the age group. For example, the smoothie name "Graft" combines guacamole and "saft" (juice in Norwegian) and potentially an association with the word "kraft" (energy in Norwegian). The "Heart-warming pasta" implied a strong emotional association. Further, they had in mind young girls as target consumers. Other marketing ideas included slogans ("Naminam is very naminam") and surprises added in the packaging (discussed in the "Big toast" and "Heart warming pasta" groups).

Online platform

The individual brainstorming in the ONL resulted in 41 posts (from 52 participants), 38 of which corresponded to product ideas. Participants proposed both healthy and unhealthy snacks (e.g. dessert-like snacks). In addition, some ideas were more wishful thinking than feasible products, e.g. *"It should be a healthy ice cream that has chocolate with vanilla flavour that tastes like normal ice cream"* or "Eternal potato gold" where the potato chips bag never gets empty. While other ideas were quite detailed as well as actionable.

Product formulation: The snack idea "MIXI" pointed out that there is an optimum of novelty: *"Not too boring and not too extreme".* As in the CFG "better-for-you" versions were suggested: *"super, both healthy and unhealthy".* This time the unhealthy was hidden in the healthy to trick parents, contrary to the idea proposed in one of the focus groups (parents tricking children in eating healthier). Two ideas focused on new shapes for finger food. Sensory specifications were identified. In two ideas sweetness was pointed out as a must: *"Should be sour but also sweet", "Good and sweet"*. Besides, two ideas described the texture in detail, indicating how it should and should not be, which suggests the importance of this sensory modality for some children,

Branding and marketing: some snacks had creative product names and were praised with slogans. Emotional associations were identified: "*When you drink this fantastic juice you become happy and your day brightens up*" and *"When you eat it you feel that your worries disappear".* Eating occasions were mentioned, which did not emerge in the focus groups. The chocolate filled pasta was suitable for Saturday night[3], whereas a fruit bar was defined as

[3] Saturday is for many Norwegian children the day when they are allowed to eat sweets.

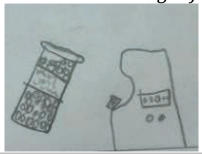
suitable for training. A futuristic idea rounded it off suggesting to replace food with pills that could be produced in any flavour.

Children's voting for a winning idea determined the idea "Sushi ball", a ball shaped sushi as winning idea in one subgroup, and "Eternal potato gold", potato chips bag that is never empty, in the second subgroup. Particularly in the second subgroup, the voting did not determine a healthy idea.

Table 3. Thematic analysis of ideas generated in creative focus groups (CFG) and an online community (ONL), as well as verbatim extracts of the discussion in the case of the CFG

	Theme	CFG 6 ideas, group brainstorming (N=3-4)	ONL 41 ideas, individual brainstorming
Product formulation	Optimum of novelty		The idea "MIXI" was described as: *"Not boring and not too extreme"*
	Better-for-you	- The "NAMINAM Burger" was made healthier by including whole wheat bread and guacamole (it was debated if guacamole can count as vegetable) - "Big toast" with lettuce and tomato - "Heart warming pasta" with vegetable or fruit filling	- Porridge with fruits - Pasta containing apple - Bun with blueberries - Carrot or apple with chocolate core (3 ideas):*"super, both healthy and unhealthy"* 
	Trick children (hide healthy)	The "Heart warming pasta" group wanted to make different types of fillings to cater to different tastes, e.g. fruit fillings for children who do not like vegetables. Also the hiding of vegetables was mentioned as a trick: *"…and then there is hidden some vegetables in between."* *"And then, and then parents can lure their kids."….*	
	Trick parents (hide unhealthy)		Carrot or apple with chocolate core (3 ideas) *"smart, as parents think that one is eating vegetables and they taste very good"*
	Sweet is tempting		- Many ideas posted were dessert-like - Pasta with apple flavour was described the following: *"Should be sour but also sweet*". - Porridge with raspberry and blueberry flavour was described: *"Good and sweet"*
	Specific textures		- Description of "MIXI", a combination of smoothie and muesli: "it is a thick smoothie (ice cream consistency)." And *"It's a nice mix and not a thin/runny smoothie."* - Description of "Sugar free filled pancakes, tropical taste": *"The filling should be liquid but not sticky. And even if it is liquid it should not be like that it comes everywhere and it should also be jelly-like."*

	New shapes	The idea for the "Heart-warming pasta" focused on making cute shapes: *"It can come in many different fun forms."* In the discussion the advantage of eating it with a spoon was mentioned.	Sushi ball: *"Seaweed covers the filled rice ball"* and Pizza on a stick (2 ideas) focused on finger food. One pizza on a stick was described with: *"You don't make your fingers dirty…"* 
	Bigger than normal	- "NAMI NAM!": *"It's a big burger. It is so big."* - "Big Toast"	Large Oreo cookie: *"Like an Oreo but they are so small. So, this is big!!!"*
	Ethnical food	The "Naminam burger" combined Indian tikka masala and ingredients from sushi	Sushi ball
	Easy hot food	- Heart warming pasta where boiling water is added to cup - Big Toast and Naminam burger that just need to be heated up	- Ready made fruit filled pancakes - Ready made porridge with blueberries - Pasta (with apple or chocolate filling) - Pizza on a stick (finger food)
Branding and marketing	Creative product names	- Heart warming pasta - NAMI NAM burger (nam=yummy) - GRAFT (associated with saft=juice and maybe guacamole as well as kraft (=energy)): for a fruit puree drink - EPAN (mixed the words for apple and banana in Norwegian) for a fruit hybrid of apple and banana	- MIXI: smoothie with muesli mix - Bruskrus (=sparkling cup) for a soda drink - Eternal potato gold: for potato chips where the package never gets empty - Epjodri (mix of apple and strawberry in Norwegian): for a fruit juice
	Packaging	- The "Heart warming pasta" could be eaten in the packaging cup - For the "Hear warming pasta" and "Big Toast" the addition of a surprise in the packaging was mentioned	See through packaging: A caramelized apple with chocolate: "*In the shop the apple should be in a see-through bag so everyone can see it.*"
	Slogans	Word play: "*Naminam is very namnam*."	- Appraisal: *"World's best"* was used twice as well as *"Epjodri makes your day brighter"* - Food that talks: *"blend me"* for a shake
	For specific occasions		- Pasta with chocolate filling was specifically invented for Saturday night.[2] - Fruit and vegetable bar: *"Can be a good training bar."*
	There are consumer segments among children as well	"Heart warming pasta" suitable for girls: *"And then they are shaped like a heart, for small girls maybe..."*	
	Emotional associations	"Heart warming pasta"	- Description of "Epjodri": *"When you drink this fantastic juice you become happy and your day brightens up"* - Pasta with chocolate filling was described as: *"When you eat it you feel that your worries disappear"*

New ways of eating	-	A machine that can produce pills in any flavour to replace common food. *"I get full at once"* 

3.4. Participants' feedback

Participants' feedback was generally positive for both settings. However, scores tended to be higher for the CFG than for the ONL (Figure 4). In both settings, the lowest scores were found for the item Challenge which could have been related to a different phrasing, however. In the CFG, Challenge was mainly rated low by the group 3 composed of the oldest children, 11-12 year old boys. The majority of participants rated their experience as "both, working and playing" in both settings. The oral feedback of participants in the CFG indicated that they enjoyed the *Create* part the most and found the *Reflect* part somewhat boring. In the ONL setting, the food blog as *Show & Tell* was ranked as favourite by the majority (64%) while *Reflect* was ranked least favourite by the majority (62%).

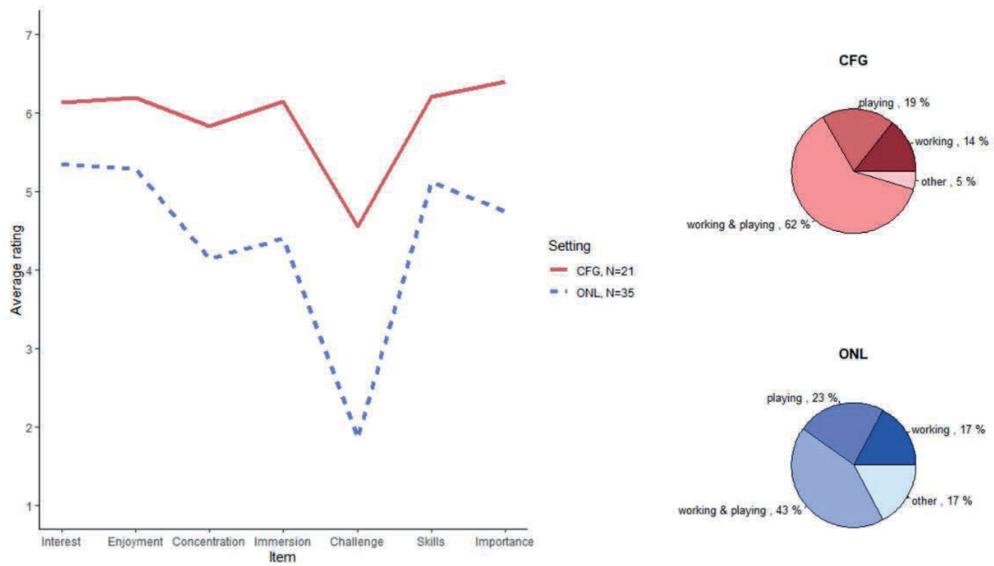


Figure 5. Average ratings provided by participants to different aspects of their experience in the CFG and ONL

4. Discussion

The present work is a first methodological attempt to include preadolescents in early idea generation stages through co-creation in a food-related context. In the multiple method setup, the first two steps explored preadolescents' snacking habits as a basis for finding ideas for new healthy snacks. In the following sections, the process and the resulting ideas are discussed from a methodological perspective, and reflections on weaknesses and strengths of the two settings are provided.

4.1. The Show & Tell – Reflect – Create as multiple method process for co-creation

In the *Show & Tell* stage, the photovoice helped participants and researchers to generate group knowledge of current snacking practices. In the CFG this step probably reflected the status quo quite accurately, as participants did not know beforehand about the usage of the snack photos they were asked to send in as preparation for the focus group. Further, the guessing game instructed and enabled participants to describe their snacks with sensory descriptions.

Meanwhile, in the ONL setting, pictures were openly shared, liked and commented. As previously observed for slightly older adolescents (Holmberg et al., 2016), food posted in a social media setting focused on special occasions. More unhealthy snacks were included, but also food that required a higher preparation degree. While the authorship of the posts was intentionally hidden in the ONL setting, many children wanted to be associated with their posts and therefore added their name in the comment field. Kietzmann et al. (2011) identified identity, conversations, sharing, presence, relationships, reputation and groups as functional blocks of social media indicating that the food blog content was dependent on psychosocial aspects in peer-to-peer interactions.

In the *Reflect* stage participants analysed and evaluated current snacking practices. Participants sorted snacks according to pleasure, healthiness but also eating occasions. In the focus group setting an in-depth learning about barriers and facilitators of pleasurable healthy snacking was possible. Further, the trained moderator could then steer the discussion to "what is missing". This possibility was not available in the ONL setting, as the exercise was individual and was not followed by a discussion.

In the final *Create* stage, most participants (38 out of 52 participants in the ONL and all six subgroups in the CFG) were able to come up with a snack idea. Most ideas were based on well-known and -liked snacks and incorporated some new element, for example the inclusion of healthier ingredients or ways to increase product appeal through marketing & branding. The group brainstorming in the CFG setting was highly engaging for participants. Through the group discussions, ideas were explained and visualized to each other, resulting in relatively rich outputs where different aspects of the product ideas were considered. The product ideas were also a compromise: in most brainstorming groups, children tried to include everyone's preferences, an effect noted in an Australian study where children created school meals in groups (Waddingham et al., 2018). In the ONL setting, the individual brainstorming gained more ideas, varying in the degree of detail, healthiness and applicability. Some ideas were elaborate, representing what was important to the individual.

4.2. Evaluation of CFG and ONL settings

The characteristics of the multiple methods process in the two settings are summarized in Table 4.

The three tasks *Show & Tell*, *Reflect*, *Create* were designed to build on each other in order to facilitate the last *Create* stage. In the CFG setting this process was to a certain extent confirmed. In the *Create* part, all ideas considered healthiness and topics that had come up in the previous tasks were taken as basis, e.g. hot meals that are easy to prepare in the context of limited cooking skills. In the ONL this evolution was less apparent. The food blog already produced some creative contributions and would have certainly been a good basis for the *Create* part. However, the tasks were implemented more than a week apart and therefore the food blog might not have been very present for the participants at the time they invented a new snack. Further, the individually performed *Reflect* task without discussion was probably not suitable to critically assess current snacking habits or serve as inspiration of what is missing.

The ONL *Create* stage represents a crowdsourcing approach for ideas. Some individual crowdsource contributions were pointing towards an innovative potential while ideas from group brainstorming were more detailed but also a compromise. The difference in the amount of detail depending on setting has been described previously by Schweitzer et al. (2015) in a non-food context with adults: focus groups developed ideas more fully, while competitions in crowdsource settings were able to generate many ideas in an efficient way. They suggested the provision of examples in online settings to increase the amount of details and mentioned that more social interactions in online settings would be beneficial. Putman and Paulus (2009) compared the originality of ideas generated by groups and individuals and classified the individual ideas to be more original. However, when it comes to food, a group compromise that already considers different preferences might be a suitable approach. Further, the pleasure of brainstorming in groups should not be underrated. The *Create* part was children's favourite task in the CFG but not in the ONL setting which should be an important criteria for successful co-creation projects (Ind & Coates, 2013).

The role of the trained moderator in the CFG was probably quite decisive for the degree to which children considered health aspects. In the *Show & Tell* and *Create* stages of the CFG children posted more health directed snacks than in the same stages of the ONL setting. Further, in the ONL a particularly unhealthy option was voted as favourite in one of the two subgroups indicating that peer-to-peer interactions are difficult to predict and will not always align with the healthy eating goal. In the *Create* stage, the strategy to "trick someone by hiding" came up in both settings, however from different viewpoints. In the CFG, the view of parents wanting to trick their children to eat healthier by hiding the healthy in the less healthy was taken, whereas in the ONL the view of the child to trick parents by hiding the unhealthy in the healthy was taken. This suggests that in the supervised CFG setting, participant's partly identified with the adult's view point but were focused on their peer's view in the unsupervised ONL setting. Previous research indicated that children's and adolescent's food choice is highly dependant on psychosocial needs to be accepted by peers (Roberts & Pettigrew, 2013; Stead et al., 2011) and that more health directed food choices were made when adults were present (Fitzgerald et al., 2010; Warren et al., 2008). In game theory, a killer type, someone that wants to test the boundaries of the game, has been identified as opposed to more constructive types, explorers, socializers and achievers (Bartle, 1996), suggesting the need for strategies on how to navigate group dynamics in ONL settings. The lack of control has been noted as disadvantage of online settings previously (Schweitzer et al., 2015).

Table 4. Comparison of the multiple-method process in the two settings, creative focus groups (CFG) and an online community (ONL).

	CFG	**ONL**
Show & Tell	Reflected status quo of snacking	Reflected status quo of snacking as well as possibilities for new snacking options (more inspirational), peer related psychosocial aspects of snacking
Reflect	In depth group discussion on drivers of liking, healthiness and eating occasion of snacks leading towards what is currently missing	Mapping of snacks and associations with liking, healthiness, eating occasion
Ideas	Few (6), detailed descriptions, group preferences (compromise, team work), relatively healthy	Many (38), varying degree of detail, individual preferences, 50% relatively healthy, "crowdsourcing" approach
Timeframe	3 sessions of 1,5 h	3 weeks
Insights in snacking habits	To high degree	To a lesser degree, peer related psychosocial aspects
Control over process	High through trained moderator	Low
Process evolution	Clear evolution	Not clear
Participant's engagement	High	Medium - high

In summary, the hereby described results show that, with the proposed processes, preadolescents can co-create food product ideas, that could be successfully applied in the early development stages of innovative healthy food and meals. However, focus groups and online settings, had some particularities: CFG facilitated teamwork, a clear group learning through the defined process, enhanced engagement and produced a few collaborative ideas considering preferences of peers. The ONL produced many ideas, varying in the degree of detail and actionability, focusing on individual preferences.

4.4. Limitations and further research

The presented study focused on first product ideas assessing them in a comparative way between the two settings from the researchers' perspectives. Further evaluations could include assessments by R&D experts as e.g. done by Christensen et al. (2017).
In the ONL setting the flow in the tasks and desired evolution was not clearly observed. This points to the necessity for further development (e.g. closer in time, more instructions given between tasks, more steering possibilities).

The results suggest the feasibility of extending the approach to other stages of the development process of new products or meals. Initial ideas could be critically evaluated in a next step and then prototyped in iterations in collaboration with chefs drawing on the concept of design thinking (Veflen, 2014). In such extended studies, product success but also the effect of participation in preadolescents' healthy eating self-efficacy and diet variety should be assessed. Olsen (2019) highlighted that creative engagement of children with chefs could be well-suited as intervention studies to diversify children's diets.
In the present study, ethical considerations were mainly focused on ensuring parental consent and children's assent, as well as being aligned with data protection rules. Commercial applications might need to consider other ethical aspects like intellectual property management strategies (Tekic & Willoughby, 2019). Children's right to participation needs to be balanced with their right to protection (Water, 2018).

We acknowledge that some of our findings might be specific to the recruited convenience sample and the Norwegian context. Children's right to autonomy and self-determination is rated especially high in Norway which might have helped the outcome of this study (Kjørholt, 2007). Further, the ONL approach requires the access to an electronical device as well as the knowledge to operate it, which are not necessarily available to all school children elsewhere. In the convenience sample that we recruited, children from different backgrounds, such as lower socioeconomic and immigration status, might have been underrepresented. Besides applications in other countries and cultures, future research could aim to recruit children from families that are most disadvantaged regarding dietary health, e.g. children from families of low socioeconomic position.

5. Conclusion

There is limited methodological research aiming to involve children actively in the idea generation of healthy food. Our results demonstrate that children (preadolescents) can create new food product ideas, with the proposed processes, using enabling and creative techniques, both in focus groups and online settings. Focus groups produced few and elaborate ideas as well as extensive insights in children's snacking practices and online setting produced many but in trend less detailed ideas as well as insights in peer related psychosocial aspects of snacking. The feedback and observations from our study, particularly in the creative focus group setting, implied that the creative approach was highly engaging for participants. Further research is necessary to assess the potential of co-creation in real product development cases considering product success but also participating children's experiences and potential short- and long-term effects on healthy eating self-efficacy and dietary diversity.

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AUTHOR STATEMENT

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Appendix 1

Feedback questionnaire used to evaluate participants' experience. The first seven questions were rated on a 7-point-scale (1=not at all, 7=very much), whereas the last question was multiple choice.

Aspect	English question
Interest	How interesting was it?
Enjoyment	How much did you enjoy what you were doing?
Concentration	How concentrated were you?
Immersion	How immersed (engaged) were you in the activities?
Challenge	Was it difficult?
Skills	How skilled were you at the activities?
Importance	How important was the activities?
Work or Play	Did it feel more like: (a) working; (b) playing; (c) both; (d) none of the above?

PAPER 3

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Children's sweet tooth: Explicit ratings vs. Implicit bias measured by the Approach avoidance task (AAT)

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ABSTRACT

The study aimed to assess the application of the Approach avoidance task (AAT) with children to measure implicit motivational tendencies towards foods differing in *sweetness* and *calorie* content and to explore the relationship between approach bias and explicit measurements of expected liking, attitudes, and hunger state and their relation to paired-preference tasks. The simplicity and game-like procedure of the AAT, where participants use a joystick to pull or push pictures, seems particularly suitable to measure implicit motivational biases in children. However, to our knowledge, this approach has not been used with children in a food related context.

Children aged 9–11 participated in the study (n = 114). Their implicit bias towards pictures of snacks was measured via AAT. The test instruction was based on pushing or pulling the joystick according to picture category, food vs. non-food: food (18 snack pictures varying in *sweetness* and *calorie*) vs. non-food (18 pictures visually similar to the respective food stimuli). Further, children rated their expected liking of the snack pictures, answered an attitude questionnaire related to health and sugar consumption, and completed two paired preference tests tasting real samples under blind condition and choosing between a sugar and no-sugar added chocolate milk take-home pack.

The percentage of non-valid AAT responses was relatively high, leading to low testing power. There was a significant difference in approach bias between food pictures and non-food pictures; approach bias was positive for food and slightly negative for non-food. Within food pictures, no significant effect of *sweetness* nor *calorie* was found. Nevertheless, children's approach biases were linked to their expected liking ratings, which revealed a clear preference towards high *sweetness* and high *calorie* snacks. Individual differences in children's approach bias to pictures differing in *sweetness* and *calorie* content were related to their hunger state but not to their attitudes or preference towards chocolate milk, indicating relevance for situational food choices. In the present study, questionnaire-based measurements (affective and cognitive attitude towards sugar, sugar craving and using food as reward) were however associated with children's preference towards chocolate milk (blind and/or informed). Higher scores in the measured attitude subscales *craving for sweet food, using food as reward, affective attitude towards sweet food* and *cognitive attitude towards sweet food* were associated with higher odds to choose the sugar added chocolate milk. Methodological considerations and recommendations with regards to the use of approach-avoidance testing with children are critically discussed.

1. Introduction

The rising prevalence of childhood overweight and obesity requires a better understanding of the mechanisms underlying children's self-directed food choices, as they often do not meet nutritional recommendations. As described in a wide body of literature, children tend to prefer sweet food (Cooke & Wardle, 2005; Mennella & Bobowski, 2015; Mennella et al., 2016; Mennella et al., 2012; Venditti et al., 2020) and energy-dense food (Cooke & Wardle, 2005; Gibson & Wardle, 2003). In this sense, previous studies have also indicated a relatively

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high focus on hedonic over health aspects during childhood (Marty et al., 2018; Marty, Miguet, et al., 2017; Nguyen et al., 2015).

According to dual processing theory, decision-making criteria can be grouped into goal-directed and automatic processes of which the latter are thought to be important drivers of food choices (Jacquier et al., 2012; Rangel, 2013). Automatic decision-making processes are expected to be influenced by implicit attitudes towards foods, i.e. favourable or unfavourable feelings, thoughts, or actions towards different foods that occur without conscious awareness (Greenwald & Banaji, 1995). Implicit attitudes have been shown to have a direct impact on eating behaviour in adults (Dubé & Cantin, 2000; Raghunathan et al., 2006) and have been postulated to be a barrier to healthy food choices (Mai et al., 2011). Köster (2009) highlighted that food habit formation occurs mostly unconsciously in childhood while conscious cognitive learning becomes more important when growing up. While adults might be able to wilfully steer their food choices to a certain degree, linking them to cognitive goals (such as health considerations), children don't reflect too deeply on their food choices. Methods that can capture children's automatic tendencies might therefore offer an advantage over questionnaire-based measurements that according to Köster (2009) assume reasoned action and planned behaviour.

Test protocols to measure automatic processes are called implicit tests and are increasingly used to study eating behaviour (Monnery-Patris & Chambaron, 2020). There are different implicit testing paradigms that address different implicit aspects (Kraus & Piqueras-Fiszman, 2018; Monnery-Patris & Chambaron, 2020). Children's implicit thinking has been investigated via categorization tasks, assessing the usage of hedonic vs. nutrition-based categorization criteria. Results showed that children more frequently used hedonic categorization, especially in their implicit thinking (Marty, Chambaron, et al., 2017) and that their implicit and explicit attitudes had an additive effect on the healthiness of their food choice (Marty, Miguet, et al., 2017; Perugini, 2005). Further, the Implicit association task (IAT) has been used to measure children's implicit bias towards healthy vs. unhealthy foods measuring the relative association of two target concepts, healthy and unhealthy food, with a positive and negative valence category. Surprisingly, studies have repeatedly found that children had an implicit bias towards healthy food while they explicitly liked unhealthy food more (Craeynest et al., 2007; DeJesus et al., 2020; van der Heijden et al., 2020). DeJesus et al. (2020) results indicated that more nutritional knowledge correlated to larger implicit biases for healthy food. None of the IAT studies linked implicit and explicit results to actual food choices.

The application of implicit reaction time tasks with children is not free from limitations; van der Heijden et al. (2020) reported a lower testing power for the IAT performed by children over adults, which indicates that the performance of the task might be challenging for children. Therefore, it is of interest to have other implicit testing procedures to measure implicit food preference patterns in children. The simplicity of the Approach avoidance task (AAT) as well as its game-like procedure, where participants use a joystick to pull or push pictures appearing on a computer screen, might be suitable to study implicit tendencies in children. However, to our knowledge, it has only been applied with children to measure implicit spider phobia, thus avoidance behaviour (Klein et al., 2011).

Approach and avoidance are thought to be more closely linked to wanting than liking, thus to actual behaviour (Kraus & Piqueras-Fiszman, 2016; Tibboel et al., 2015). While Tibboel et al. (2015) doubted that the AAT can measure wanting, there are AAT studies that would support this theory: people high in the trait food craving displayed larger approach biases to food (Brockmeyer et al., 2015). Booth et al. (2018) used a closely related but cognitively more challenging protocol (the Manikin task) to measure approach tendencies to sweet snacks in adolescents placing approach bias as moderator between impulsivity trait and uncontrolled eating behaviour. Further, the AAT has been successfully applied as an intervention for overweight children to learn to resist visual food cues (Warschburger et al., 2018) indicating a tight link to actual behaviour.

In this context, the aim of the study was threefold: i) to assess the application of the Approach avoidance task with children to measure implicit motivational tendencies towards food, ii) to evaluate approach bias towards foods differing in *sweetness* and *calorie* content, and iii) to explore the relationship between approach bias and explicit measurements of expected liking, attitudes, and hunger state and relate results to paired-preference tasks (representing food choice). It was hypothesized that children would display more positive approach biases towards high *sweetness* and high *calorie* foods. Further, it was assumed that implicit approach bias would be related to children's preferences of a sugar and no-sugar added chocolate milk (blind and informed choice).

2. Materials & methods

The study consisted of several tasks including the implicit Approach avoidance task (AAT), explicit questionnaires of attitudes, hunger state and expected liking as well as blind and informed paired preference task of chocolate milk as displayed in Fig. 1. Two workstations were set up. Children (9–11 years old) in groups of a maximum of 12 performed the tests and switched workstations once both groups were finished. Approximately half of the children performed the test before and half after lunch. All results were collected electronically. In each workstation children logged in with a three-digit code distributed as stickers at the beginning of the study. This allowed us to connect the results of the two workstations while ensuring that participants were not identifiable in the data.

2.1. Participants

The study was conducted at Vitenparken Campus Ås within a science outreach program that is offered to school classes in the Akershus region. A total of 114 children between 9 and 11 years old participated (52% girls; 9 years old n = 68, 10 years old n = 36, 11 years old n = 10). Children visited the science centre with their school classes and teachers. They had different science lectures, activities and exhibitions throughout the day, among those the current study.

A protocol of the presented study was approved by the Norwegian Centre for Research Data, reference 476380. Before the test, parents were informed about the experiment via the school communication app, along with an electronic consent form. Some parents forgot to sign the form. In discussion with the teachers who accompanied the school classes, children with a missing consent form were allowed to participate as the tests belonged to their class activity. Passive consent by the parents through the information via school app was regarded sufficient for the presented study, due to the anonymized setup where participating children were not identifiable directly or indirectly which is the best-case scenario regarding data protection (General Data Protection Regulation (GDPR), EU regulation n° 2016/679) and the low risk of experiencing harm during the test. All children were orally asked for their assent to participate in the study and food allergies or intolerances that would not allow the tasting of the chocolate milk samples. They were also informed that they could leave the test at any time without consequences.

2.2. Implicit reaction time measurement – Approach avoidance task (AAT)

The Approach avoidance task (AAT) was implemented with the software Inquisit Millisecond 5.0 using joysticks (Logitech G Extreme 3D Pro). Seats were adjusted according to children's height and joysticks were placed on the side of children's writing hands. Prior to the task, a researcher gave a detailed introduction and encouraged children to test the movement of the joystick.

Children were required to react to a single picture (stimuli) displayed in the centre of the screen of a laptop computer, by pulling or pushing

Work station 1	Hunger state rating (scale)	Implicit Approach Avoidance task (AAT)	Rating of sweetness intensity and expected liking of food pictures used in AAT
Work station 2	Paired preference test (take-home chocolate milk packs)	Demographics (age and gender), self-reported attitudes	Paired preference test (blind tasting of chocolate milk samples)

Fig. 1. Test setup.

the joystick, depending on the picture category and instruction of the test part. The task consisted of two test parts with opposite test instructions that required pulling or pushing according to the picture category (food vs. non-food). This setup corresponds to a feature-relevant task instruction where the reaction criterion is based on picture content which had been found to have a larger testing power regarding discrimination between picture groups (Lender et al., 2018). Other AAT studies (e.g. Brockmeyer et al., 2015; Piqueras-Fiszman et al., 2014) have used a feature-irrelevant setup where reaction criteria were, e.g. based on picture orientation (portrait vs. landscape). In such settings, image processing might be less conscious which can result in lower testing power.

Pictures were enlarged when pulled and shrunk when pushed creating the illusion of coming closer/going farther away. Further, error messages were included for wrong answers so participants could correct the classification criterion in case they forgot it. The order of test instruction ("pull food and push non-food" or "push food and pull non-food") in test part was balanced across participants.

All picture stimuli were retrieved from the image database "Food-pics" (Blechert et al., 2014). The stimuli set consisted of 18 snacks (food category), commonly eaten by Norwegian children, representing approximately one portion. The snacks were selected based on their sweetness level (low, medium, high) and their calorie content (low, high, as per "Food-pics"' database). Sweetness categories were assumed a priori by the experimenters and checked a posteriori by collecting sweetness ratings from participants (Spearman correlation, rs = 0.41). Each food picture was matched to a non-food picture (non-food stimuli) regarding shape and colour (examples in Supplementary material, Fig. 1). In total there were 36 test stimuli, 18 food and 18 non-food pictures. Snacks are listed in Table 1 according to sweetness and calorie category including snack picture number and matching non-food picture number in the "Food-pics" database (Blechert et al., 2019).

Each test instruction block consisted of 16 practice trials to train the response criterion with different pictures than the ones used in the test

Table 1
Design of Experiment of pictures used for the Approach avoidance task (AAT) (picture numbers in the "Food-pics" database (Blechert et al., 2019)).

	Food pictures (food picture/matching non-food picture)	
	High calorie (160–621 Kcal/100 g)	Low calorie (16–93 Kcal/100 g)
High sweetness	Gummi candy (#153, #1139) Ice cream (#25, #1314) Chocolate bar (#287, #1004)	Banana (#789, #1256) Grapes (#284, #1072) Watermelon (#829, #1276)
Medium sweetness	Muesli bowl (#181,#1136) Waffle (#9, #1060) Jam toast (#347,#1080)	Pear (#402,#1308) Blueberries (#202,#1137) Orange juice (#358,#1094)
Low sweetness	Cheese toast (#593,#1147) Chips (#26,#1208) Cashew nuts (#110,#1129)	Milk (#573,#1017) Carrot and cucumber (#215, #1311) Cherry tomatoes (#275,1132)

(#0372, #0865 for food; #1265, #1113 non-food) and 72 measurement trials consisting of two repetitions of the 36 stimuli pictures. In each repetition, pictures were presented in a randomized order. For the measurement, reaction time, at a 30-degree tilt of the joystick, as well as the correctness of the responses were registered. The whole test lasted approximately 15 min, varying according to children's reaction speed.

2.3. *Explicit questionnaire-based measurements*

Electronic questionnaires were implemented in the software EyeQuestion.

Hunger level:

Children rated their hunger level (7-point scale with three anchors "I am hungry", "I am neither hungry nor full" and "I am full") prior to the Approach avoidance task (AAT).

Sweetness intensity and expected liking of food pictures used in AAT:

After the implicit test, children rated their expected liking on a 7-point hedonic scale and their expected sweetness intensity (category scale: "Not sweet", "A bit sweet", "Pretty sweet", "Very sweet") of each of the food pictures (Table 1), to check the sweetness levels defined by researchers. The food pictures were presented in a sequential monadic balanced order.

Attitudes to healthy eating and sweet food:

Children answered an attitude questionnaire with three subscales extracted from the Health and Taste questionnaire by Roininen et al. (1999) (General health interest, Craving for sweet food and Using food as reward) with slight adjustments to fit the age group based on a pilot study (see Supplementary material 1, Table 1). Further, two scales, affective and cognitive attitudes towards sweet food, from a study with children of the same age group (Takemi & Woo, 2017) were included. Questionnaires were translated from English to Norwegian and pilot-tested with a small group of children. For all attitude-based measurements, 7-point agreement-to-statement scales were used.

2.4. *Chocolate milk preferences*

To link children's implicit and explicit attitudes to their actual preferences, a chocolate milk case study was used, where children chose between two commercially available chocolate milks with added and no-added sugar in two instances, a blind tasting, and a take-home paired preference test.

2.4.1. *Take-home paired preference test:*

Children chose between two chocolate milk packs (Work station 2, Fig. 1). Children made their choice upon entering the room without knowing about the test scope. They were informed that they could choose one of the chocolate milks as a token for their participation. The main difference between the packs was the presence/absence of the claim "No added sugar". There were slight variations in the pack design but they were generally similar, with a comic figure of a cow. However, the "No added sugar" version had the claim "New" in a yellow flash. Children recorded their take-home preference at the start of the test, clicking on their choice on a screen that displayed the photos of both packs next to each other.

2.4.2. Blind paired preference test

After the attitude and demographics questions, children tasted the two chocolate milks and chose the one they preferred. Samples were served in black plastic cups that masked slight colour differences and were coded with two symbols similar in shape, a cloud and a flower. Chocolate milk recipes differed more than regarding sugar content, as they are optimized products in the market. The "No added sugar" version had been sweetened by lactose hydrolysis. A pre-tasting by the researchers confirmed a perceivable difference in sweetness intensity.

2.5. Data analysis

All analyses were performed in R, version 4.0.4. Significance was determined based on an alpha of 5%. The R package "mixlm" (Hovde Liland, 2019) was used for linear mixed ANOVAs, "lmerTest" (Kuznetsova et al., 2017) for mixed linear regression and logistic regression models and "FactoMineR" (Lê et al., 2008) to perform a Multiple factor analysis (MFA).

2.5.1. Data pre-processing

Children with insufficient data quality in the Approach avoidance task (AAT) (n = 15) and missing data due to software problems in the expected liking (n = 1) were deleted from all analysis resulting in 98 children included in the analyses. For chocolate milk paired-preference tests three additional answers were missing (due to lactose intolerance or milk disliking) resulting in 95 answers for paired-preference tests.

2.5.2. Assessment of AAT data structure

AAT data was pre-processed according to Klein et al. (2011), excluding data points with errors or reaction times that exceeded test cut off values (<200 ms and >5000 ms) and individual cut off values (±2*standard deviation), (=outliers) and excluding children with a very high amount (>25%) of missing data. The remaining dataset contained 11% errors, 5% outliers exceeding individual cut-offs and 1% outliers exceeding test cut-offs, resulting in 15% responses that were deleted for the analysis.

Error and outlier structures were assessed by a mixed logistic regression including *test part, movement* with the joystick, *picture category, gender*, *age* and the interaction *gender* × *age* as fixed and *child* nested in *age* × *gender* as random variables. In the same way, reaction time was tested by a mixed regression model. Results are presented in Supplementary material 2.

2.5.3. Approach bias according to picture category (food vs. non-food)

The approach bias was calculated by subtracting the reaction time for pulling from the reaction time for pushing, per picture. The mean of the two repetitions was used. Approach bias according to picture category (food and non-food) was tested with a mixed ANOVA with *picture category* as fixed, *child* as well as the interaction *picture category* × *child* as random factors.

2.5.4. Approach bias and expected liking of food pictures

For comparison, the same mixed ANOVA models were calculated with approach bias and expected liking ratings as dependent variables. Using the design of experiment factors (sweetness: low, medium, high and calorie content: low, high), pictures were tested for *sweetness*, *calorie*, the interaction *sweetness* × *calorie* as fixed factors and child and the two- and three-fold interactions as random factors.

Supplementary material 3 presents additional analyses. To check the results generated by design of experiment, children's *individual sweetness ratings* as well as *calorie* estimates from the "Food-pics" database were tested by a mixed regression model. A second model also included visual parameters of snack pictures which could have confounded the estimation of *sweetness* and *calorie* content.

The correlation between approach bias and expected liking was estimated by a mixed regression model with expected liking as fixed and child as a random variable. Further, the two measurements were compared visually by multiple factor analysis (MFA). The Multiple factor analysis overlayed the two measurements, each matrix had snack pictures as rows and children's responses as columns. Columns were centred and standardized for the Multiple factor analysis.

2.5.5. Individual differences in approach bias and expected liking

To compare children's approach bias and expected liking to other measurements, differences between the design of experiment levels were calculated. The associations with continuous variables (*attitude* subscales and *hunger state*) were tested by Pearson correlations, categorical variables by unpaired (two-sample) two-sided t-tests in the case of binary variable (*gender*) and ANOVA (*age*).

2.5.6. Implicit and explicit measurements to predict food choice

The association of implicit and explicit (continuous) measurements with chocolate milk paired-preference (=food choice) was tested by unpaired (two-sample) two-sided t-tests.

3. Results

3.1. Approach bias according to picture category (food vs. non-food)

Children's approach bias differed significantly between food and non-food pictures (p-value = 0.005). Their approach bias was positive for food (M = 40.0 SD = 346.4) and slightly negative for non-food (M = −17.8, SD = 361.0). Positive approach biases indicate that the pulling movement when looking at the stimulus was faster than the pushing, indicating approach tendencies, while negative values indicate the opposite: avoidance tendencies.

3.2. Approach bias and expected liking of food pictures

The effects of *sweetness*, *calorie* and their interaction within food pictures did not have a significant effect on children's approach bias (Table 2). There were no significant individual differences regarding *sweetness* (*sweetness* × *child*) indicating that children did not systematically differ in how this factor influenced their reaction times. The interaction *calorie* × *child* was significant, indicating that children differed systematically in their approach biases towards high and low *calorie* snacks.

There were significant differences in children's expected liking according to *sweetness*, *calorie* content, and their interaction (Table 2). Children expected to like the foods in the high *sweetness* level more than those in the low and medium *sweetness* level. Also, foods in the high *calorie* group were expected to be liked more, but only in the low and high *sweetness* group (Fig. 2). There were no significant individual differences regarding the effect of *sweetness* (*sweetness* × *child*) on explicit liking, indicating that most of the participants liked a high *sweetness* level most. The interaction between *calorie* and *child* was significant, indicating individual differences in the effect of *calorie* on expected liking.

A mixed regression analysis confirmed that children's expected liking was significantly associated with children's approach bias (Estimate = 9.9 ms, 95% CI 1.2–18.7 ms). Fig. 3 displays children's approach bias and expected liking configurations of the food pictures overlayed by a multiple factor analysis which explained only 21% of the variance, indicating that the two measurements differed despite the significant association. The configuration of the factors *sweetness* and *calorie* that were projected on the multiple factor analysis plot based on the location of the respective snack pictures is shown in Fig. 3b. High *sweetness* was separated from low and medium *sweetness* in the first dimension. Further, a separation according to *calorie* in a diagonal was apparent,

Table 2
Sweetness, *calorie* and their interaction of the food pictures was analysed with a mixed ANOVA with child as random factor and the interaction between factors and child. Approach bias was the continuous response for implicit responses and expected liking for explicit responses.

Dependent variable	Factors	DF	SS	MS	F-value	P-value
Implicit: approach bias to food pictures	Sweetness	2	245,238	122,619	1.2	0.308
	Calorie	1	120,190	120,190	1.0	0.323
	Child	97	25,632,992	264,258	2.0	**0.002**
	Sweetness × calorie	2	67,771	33,886	0.4	0.687
	Sweetness × child	194	20,099,648	103,606	1.2	0.167
	Calorie × child	97	11,821,755	121,874	1.4	**0.040**
	Sweetness × calorie × child	194	17,495,298	90,182	0.8	0.980
	Error	1078	245,238	122,619		
Explicit: expected liking of food pictures	Sweetness	2	251	125	49.29	**<0.001**
	Calorie	1	111	111	22.33	**<0.001**
	Child	97	872	9	2.07	**0.002**
	Sweetness × calorie	2	85	43	13.47	**<0.001**
	Sweetness × child	194	494	3	0.8	0.937
	Calorie × child	97	481	5	1.57	**0.004**
	Sweetness × calorie × child	194	615	3	1.09	0.199
	Error	1176	3410	3	–	–

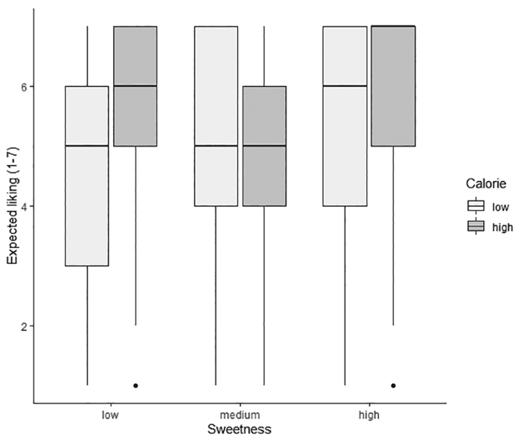

Fig. 2. The factors *sweetness*, *calorie* as well as their interaction had a significant effect on children's expected liking ratings.

high towards the lower right corner and low towards the upper left corner. In the score plot based on implicit and explicit responses "Chips" was placed in the high *sweetness* cluster and "Banana" was not in the high *sweetness* cluster (Fig. 3a). For 54% of the children, the implicit and explicit responses displayed in the loading plot (Fig. 3c) were directed towards the right-hand side of the first dimension (high *sweetness*). Almost all (91%) children's expected liking vectors were directed towards the right hand side of the first dimension (high *sweetness*) while children's approach bias did not show a defined pattern; the vectors pointed in all directions.

3.3. Individual differences in approach bias and expected liking

In order to compare approach bias and expected liking tendencies to different snack groups, differences between factor levels were built. As the Multiple factor analysis (Fig. 3b) separated the high *sweetness* level from medium and low, the difference high – low & medium *sweetness* was correlated to other measurements (demographics, attitude, hunger state). The difference high – low *calorie* was included, as the mixed ANOVAs for approach bias as well as expected liking (Table 2), indicated a systematic difference between children for the factor *calorie* (significant interaction *child* × *calorie*).

Age and gender were unrelated to individual differences regarding approach biases and expected liking to the studied snack groups (Table 3). Some attitude subscales correlated to individual differences in children's expected liking according to *calorie* content but not to *sweetness* nor implicit approach bias (Table 3). Children who were hungry showed larger approach biases and expected liking ratings for high caloric compared to low caloric snacks as well as lower approach biases towards the high sweetness vs. medium and low levels (Fig. 4). As children participated either before or after lunch, their hunger levels differed systematically. There were similar proportions of hungry, neither hungry nor full and full participants (N = 39, N = 31, N = 28).

3.4. Implicit and explicit measurements and chocolate milk preference

Neither individual differences in children's approach bias nor expected liking for *sweetness* or *calorie* were associated with their chocolate milk preferences (Table 4). The attitude subscales, *affective* and *cognitive attitude towards sugar*, *sugar craving* and *using food as reward*, were associated with children's chocolate milk preference (blind and/or informed). Higher scores in the measured attitude subscales were associated with higher odds to choose the sugar added chocolate milk.

4. Discussion

The present research work aimed to apply the Approach avoidance task (AAT) to investigate children's automatic approach tendencies for the first time in a food-related context. The objective was to study if implicit testing would offer additional insights to explicit measurements of attitudes and liking towards foods of different sweetness and calorie content and if implicit biases could explain children's actual food choice.

4.1. Approach bias to food vs. non-food stimuli

Children displayed a positive approach bias towards food (snack) pictures in general and a slightly negative approach bias to non-food pictures. The fact that non-food pictures had slightly negative approach biases confirmed that approach biases to food were not just the result of different movement speeds in general (pushing the joystick faster away than pulling towards) but linked to picture content. Thus, it can be concluded that snack pictures caused an approach behaviour in children. Similar results have been reported in previous AAT of comparable setups in adults (Kahveci et al., 2020; Lender et al., 2018).

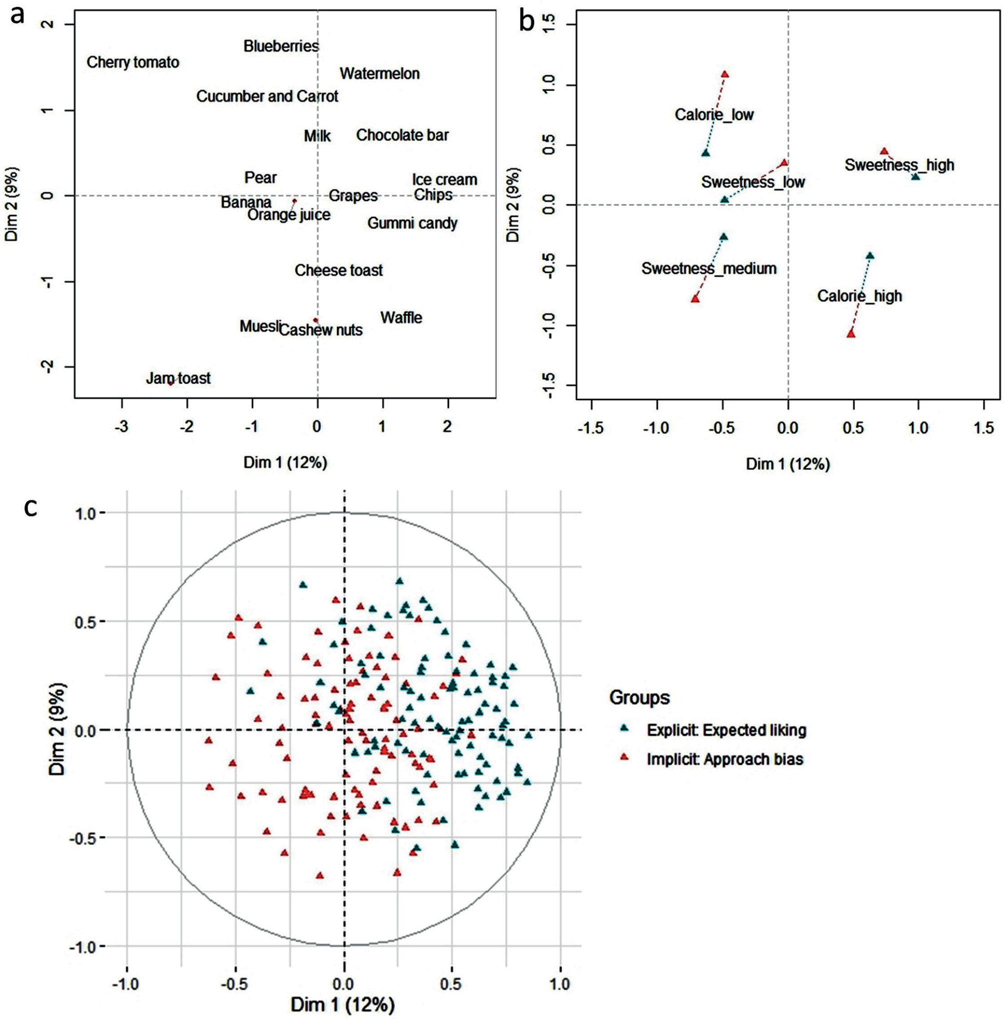

Fig. 3. Multiple factor analysis of implicit (Approach bias) and explicit (Expected iking) responses to snack pictures differing in sweetness level and calorie content. Both matrices were centred and standaridzed with snack picture as row and child as column. a: score plot showing snack pictures (exact location in centre of text unless marked with red dot), b: projection of design of experiment factor levels with lines showing implicit and explicit location, c: loading plot representing children regarding their explicit and implicit response. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.2. Approach bias and expected liking of food pictures

The present study did not find significant differences in approach bias according to sweetness and calorie levels in the selected snack pictures. This was also not the case in a study with adults where calorie content, individual food preferences and food deprivation were investigated in relation to approach bias through a touchscreen-based AAT, with a wide range of food items (Kahveci et al., 2020). The lack of discrimination among food pictures in the present study could be linked to the low test power of the AAT due to high error and outlier rates which did not allow to measure relatively small differences between appealing snack pictures (further discussed in 4.5 Methodological considerations and recommendations).

Expected liking ratings discriminated the food stimuli according to sweetness, calorie content, and their interaction. As in previous studies (Cooke & Wardle, 2005; DeJesus et al., 2020; Ervina et al., 2020; van der Heijden et al., 2020) children expected to like snacks high in sweetness and high in calorie more.

We were able to see some common and some distinct patterns between the implicit and explicit responses. On one side, the regression analysis confirmed that children’s expected liking ratings were significantly correlated with children’s approach bias, in line with that described by Kahveci et al. (2020) in adults. However, it is interesting to note, that expected liking and implicit bias were not representing similar tendencies for all children, as suggested by the Multiple factor analysis loading plot. While half of the children showed expected liking

Table 3
Individual differences in explicit and implicit responses to snack pictures linked to other measurements: Demographics, health and taste questionnaire subscales, behavioural intention subscales, hunger state and chocolate milk preference. Continuous variables (health and taste subscales, behavioural intention subscales, hunger state) were tested by Pearson correlation (correlation coefficient and p-value reported), categorical variables by unpaired t-tests (chocolate milk preference, gender) and ANOVAs (age).

	Variables	Frequency for categorical/mean (SD) for continuous variables	High – medium & low sweetness		High – low calorie	
			Implicit: approach bias	Explicit: expected liking	Implicit: approach bias	Explicit: expected liking
Demographics (N = 98)	Gender	Girls:47%, boys:53%	T(96) = 0.1 p = .922	T(96) = 1.7 p = .090	T(96) = 1.7 p = .100	T(96) = 1.0 p = .317
	Age	9: 62%, 10: 29%, 11: 9%	F(2,95) = 0.4 p = .642	F(2,95) = 1.8 p = .175	F(2,95) = 0.1 p = 0.904	F(2,95) = 1.1 p = 0.345
Attitude subscales (N = 98)	General health interest (1–7) (α = 0.41)	4.4 (0.9)	−0.18 p = .080	0.04 p = .697	−0.05 p = .646	−0.06 p = .579
	Craving for sweet food (1–7) (α = 0.69)	4.7 (2.0)	0 0.14 p = .167	0.08 p = .445	0.09 p = .390	**0.32** p = **.001**
	Using food as reward (1–7) (α = 0.64)	4.1 (1.1)	0 0.01 p = .930	−0.02 p = .859	−0.06 p = .536	**0.37** p < **.001**
	Affective attitude towards sweet food (1–7) (α = 0.64)	4.4 (0.8)	0 0.01 p = .911	0.02 p = .866	−0.00 p = .978	**0.41** p < **.001**
	Cognitive attitude towards sweet food (1–7) (α = 0.52)	4.3 (0.6)	0.01 p = .919	0.01 p = .919	−0.04 p = .666	**0.41** p < **.001**
State (N = 98)	Hunger (1–7)	4.2 (1.7)	**−0.24** p = **.017**	0.06 p = .552	**0.25** p = **.014**	**0.26** p = **.010**

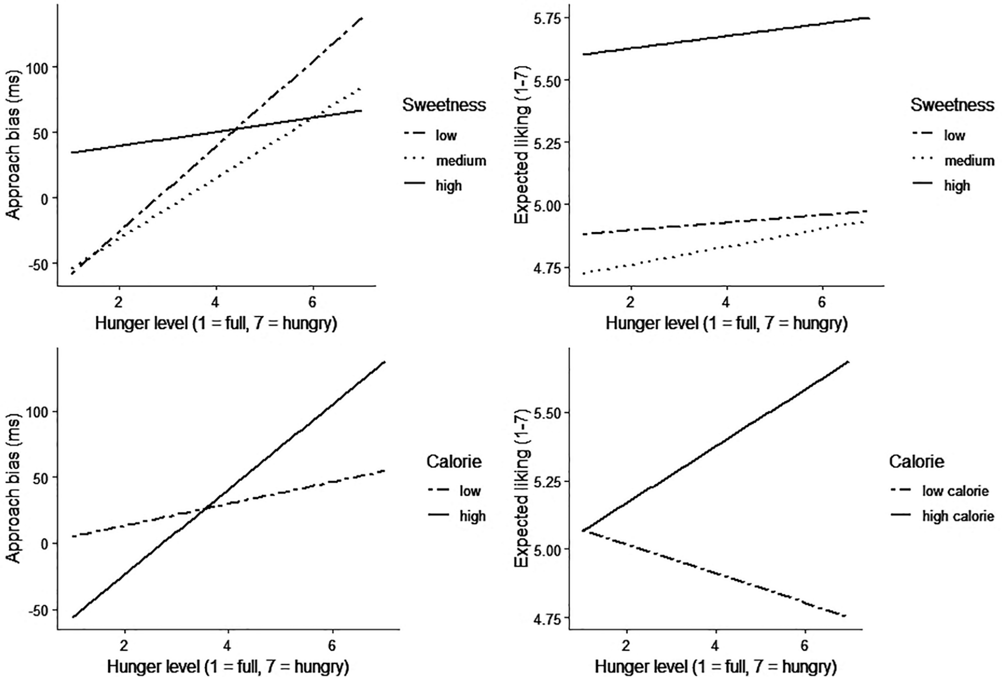

Fig. 4. Implicit (Approach bias) and explicit (Expected liking) according to hunger level. Regression lines were drawn per sweetness level and calorie content. There were similar ratios of hungry, neither hungry nor full and full participants (N = 39, N = 31, N = 28).

responses in line with their implicit bias responses (associated with high sweetness levels), many other children had opposite patterns for both responses. These results link back to what was suggested by Piqueras-Fiszman et al. (2014): implicit test results may be more sensitive for studying individual differences amongst certain groups of consumers and are not necessarily linked to (positive) affective ratings measured via visual analogue scales (VAS) (e.g. liking or wanting).

4.3. *Individual differences in approach bias and expected liking*

There were no significant individual differences regarding the effect of sweetness on explicit liking, indicating that most of the participants liked the foods with a high sweetness level most. However, we observed individual differences in expected liking as related to calorie level which were related to attitude subscales (*craving for sweet food*, *using food as reward*, *affective* and *cognitive attitude towards sweet food*) and children's

Table 4
Two-sided unpaired t-tests comparing implicit and explicit measurements with paired-preference tasks. N was reduced to 95 in this part because three children did not participate in the chocolate milk preference task due to disliking/lactose intolerance/milk allergy.

			Blind paired preference test (tasted samples)	Take-home paired preference test
			79% preferred added sugar, 21% preferred no added sugar	74% preferred added sugar, 25% preferred no added sugar
Implicit	Approach bias	High – medium & low sweetness	T(93) = 1.2 p = .235	T(93) = 0.4 p = .671
		High – low calorie	T(93) = 0.6 p = .554	T(93) = −0.4 p = .670
Explicit	Expected liking	High – medium & low sweetness	T(93) = 1.4 p = .167	T(93) = 1.1 p = .275
		High – low calorie	T(93) = 1.4 p = .161	T(93) = 0.5 p = .645
	Hunger state	Hunger level	T(93) = 1.2 p = .235	T(93) = -1.2 p = .224
	Health and Taste	General Health interest	T(93) = 0.1 p = .898	T(93) = 0.8 p = .433
		Craving for sweet food	T(93) = 1.8 p = .063	T(93) = 2.2 p = **.027**
		Using food as reward	T(93) = 2.2 p = **.028**	T(93) = 2.5 p = **.015**
	Attitudes towards eating sweets	Affective attitude	T(93) = 2.7 p = **.008**	T(93) = 3.5 p < **.001**
		Cognitive attitude	T(93) = 2.5 p = **.013**	T(93) = 3.0 p = **.003**

hunger level.

With regards to approach bias tendencies, individual differences were not correlated with explicit attitudes. Interestingly, there was a significant link to children's hunger state. The children in this study seemed to implicitly regulate their approach bias response to snack pictures according to their appetite level. Children who were hungry (who performed the AAT just before their lunch) had a stronger approach bias to high caloric snacks and snacks with medium and low sweetness level, so they were significantly more attracted to calorie-dense, non-dessert food in the case of being hungry. Kahveci et al. (2020) did not find food deprivation to produce a larger approach bias towards high calorie food in adults. In our study hunger state also influenced children's explicit expected liking rating of snack pictures: children who were hungry showed larger expected liking ratings for high caloric snacks. However, the effect was only seen for calorie content and not for sweetness level. This indicates that the approach tendency patterns may have been more predictive of situational food choices while expected liking was somewhat more static. Kraus and Piqueras-Fiszman (2016) highlighted that approach or avoidance tendencies may be more linked to dynamic, motivational states, associated with the specific state (e.g. hungry vs. full) or a momentaneous desire to eat, while liking represents an evaluative concept, linked to habitual preferences. A previous study investigating the effect of hunger state on liking vs. wanting (measured by forced-choice tasks) of high vs. low fat and sweet vs. savoury foods (Finlayson et al., 2007) found similar diverging patterns. So, results of the present work add to the literature, suggesting that implicit approach bias interpreted as a representation of automatic wanting and explicit liking ratings may be representing different driving forces behind food behaviour.

4.4. Implicit approach bias and explicit measurements as related to chocolate milk preference

In the present study, neither children's approach bias nor expected liking nor their hunger state were associated with their preference for a sugar vs. non-sugar added chocolate milk either in the blind or informed paired-preference task. Despite low internal consistency, attitude measurements (*craving for sweet food*, *using food as reward*, *affective* and *cognitive attitude towards sweet food*) were significantly associated with children's preferences of chocolate milk. This suggests that the involved age group (9–11 y. o.) was able to describe their eating behaviour through the attitude questionnaires, attesting them a certain degree of introspection. However, the low internal consistencies (Cronbach's alpha smaller than 0.7) of the attitude subscales indicate that self-administered attitude questionnaires have limitations with the involved age group as well.

The blind and informed chocolate milk paired preference tests were set up to assess if children with an implicit bias towards sweet or high caloric foods would more frequently choose the higher caloric option (added sugar sample in the informed take-home test) and/or the sweeter one (added sugar sample in the blind tasting preference test and take-home test); and if their explicit attitudes were linked to their preferences. The authors acknowledge the prediction power of the performed preference tests is limited and more research is needed to assess the potential link of implicit bias measurements with actual food choice patterns. The paired-preference task was chosen to have ecological validity as Norwegian children might be confronted with the choice scenario in a grocery store (packs were real commercial products) and to ensure familiarity, as the samples are offered as part of the "school milk program" in Norwegian schools. As a downside, the commercial samples (packs and formulations) contained some confounders which could have biased or added noise to the results. The packaging contained information about calorie content (61 kcal/100 g vs. 41 kcal/100 g) and sweetness intensity (no info vs. "No sugar added"), the variables under study in this research. However, the claim "New" on the packaging of the no-sugar added chocolate milk could have shifted the focus of attention when choosing, or prevented neophobic children from choosing this option. The tasted samples in the blind test differed in sugar content and resulted in a perceivable difference in sweetness intensity, having comparable sensory profiles, as evaluated by the research team. However, the non-sugar added recipe had been optimized regarding other ingredients which could have confounded the assessment of preferences towards sweetness intensity. Children might also have been more familiar with the sugar added recipe, that had been for longer in the market. Food memory is particularly good at detecting novelty which could result in rejection (Morin-Audebrand et al., 2012). A more general limitation was the limited focus of testing preferences on only one food category (chocolate milk) as indicator of more general food choice patterns. Marty, Miguet, et al. (2017) used for this purpose a buffet set-up where children could make several choices to measure children's preference patterns, an approach that could have presented a more valid food choice scenario. A choice scenario based on a buffet composed of similar snacks to those assessed via AAT and liking (picture stimuli) might have been more predictive and should be considered for future studies. However, the test procedure in the present study, involving questionnaires, implicit testing and two preference tests was, on one hand, long enough for children, and on the other, entailed numerous methodological complex decisions that made us settle for a simple preference testing approach. Even with their limitations, the obtained results gave us a first indication of how to link implicit motivations and explicit preferences and provided new knowledge that can be utilised in future test designs.

Results suggest that social desirability may not bias explicit measurements in self-administered test settings with children in the same way as it might be the case with adults, as e.g. found by Raghunathan et al. (2006). According to these authors, the majority of adults claimed to like healthy but ultimately chose unhealthy food. In the present work, the majority of participating children rated unhealthy snacks (=high in calorie and sweetness) higher in expected liking than healthy snacks and also chose the unhealthier option (chocolate milk with sugar over no-sugar added). Further, their self-reported attitudes were associated to their chocolate milk preference. Implicit testing might be more relevant in populations where implicit motivation and liking, representing goal-directed intention, stand in opposition, e.g. overweight children who are trying to lose weight but do not manage. The AAT has come into application with overweight adults (Kakoschke et al., 2017; Maas et al., 2016; Paslakis et al., 2016) and as intervention to "retrain" overweight children (Warschburger et al., 2018).

4.5. Methodological considerations and recommendations

When planning and evaluating the study we were confronted with the question, if the AAT is most suitable to compare individuals regarding their approach biases as done in most previous food-related AAT studies (Booth et al., 2018; Brockmeyer et al., 2015; Kahveci et al., 2020; Kakoschke et al., 2017; Lender et al., 2018; Maas et al., 2016; May et al., 2016; Paslakis et al., 2016; Piqueras-Fiszman et al., 2014; Rohr et al., 2015) or if differences between food categories could be investigated as well. We decided to focus on both, as done in a few studies (Kahveci et al., 2020; Maas et al., 2016; Paslakis et al., 2016; Rohr et al., 2015). First, investigating children's general approach bias tendencies and then investigating individual differences in the assessments. However, we did not find significant effects of the design of experiment parameters (*sweetness* and *calorie*) within snack pictures, as discussed above. This question remains open and future studies should include varying levels or relevant product features, based on controlled design of experiment, to better understand the applicability of AAT and other implicit methods to product differentiation.

Measuring reaction time is likely to contain a high amount of noise (due to distraction), which might be more pronounced in children, as noted by (van der Heijden et al., 2020), who compared the test power of children and adults in the implicit association task. Although the pulling and pushing of a joystick as a reaction tool in the AAT is particularly easy, the task still required children to stay focused over an extended period (appr. 15 min in the presented study). In the present study, 15 children had to be excluded from the data analysis due to large error and outlier rates and the resulting AAT dataset contained 15% missing values which reduces test power which was higher than in previous studies with adults (e.g. Lender et al., 2018).

The multidimensional characteristics of pictures as test stimuli, makes the setup of a suitable test design challenging, as there are many potential confounders. In our test, visual aspects (shape and colour) of food were controlled for by the inclusion of visually similar non-food items. However, within food items, no standardization was easily attainable if the objective was to vary levels of sweetness and calories. Foroni et al. (2016) found that human's arousal is linked to colour, however only in food not visually similar non-food pictures. Therefore, colour imbalances between factor levels of snacks could have biased findings. We explore this aspect when checking data quality (Supplementary material 3) but no visual picture features (such as redness or contrast) had a significant effect on Approach bias. Further, picture meaning can be confounded as well. Coricelli et al. (2019) proposed natural vs. processed food as an additional dimension which was almost 1:1 represented by the factor *calorie* in our study (the high calorie foods were processed to a certain degree, low calorie were not). However, our results may indicate that calorie content rather than processing level was decisive for children's response as implicit and explicit tendencies towards high calorie content correlated to children's hunger level. Further, our results suggest a main separation between the frequently consumed and the more special snacks (more seasonal or usually restricted by parents), as shown by the Multiple factor analysis, an aspect that could be worth investigating further. It could also be of interest to compare two extreme food groups as done by Piqueras-Fiszman et al. (2014). They compared individuals regarding approach and avoidance towards appealing and disgusting foods and also assessed the role of their hunger state. With children, food neophobia topics could potentially be explored this way.

In the feature-relevant task instruction chosen in the presented study, the response criteria are based on the stimulus picture content; in the feature-irrelevant used by other authors, the task focuses on a different aspect (e.g. landscape and portrait format of stimulus picture). Lender et al. (2018) found larger effects comparing food and non-food pictures in a feature-relevant setting. It could be that in feature-irrelevant task instructions, participants are so much focused on the task goal that they do not perceive the picture content. Selective attention has been well demonstrated, e.g. in the Nobel price winning "Gorilla experiment" (Simons & Chabris, 1999). It can be assumed that the discrimination between stimuli could be even weaker in feature-irrelevant AAT tasks where stimulus processing mostly occurs subliminally. However, more than just assuring the processing of picture content, similar as in the Implicit association task, the feature-relevant AAT task instruction brings the classification concepts into participants' consciousness. This could extend participants' response towards the concept of the two groups (food vs. non-food in our study) rather than the presented stimuli in the pictures. Lavender and Hommel (2007) argued that the intention to act upon affect will lead to approach behaviour. In our setup participants were aware of the food vs. non-food group and were instructed to act upon this criterion. But they were not aware and therefore had also no intention to act upon the factor levels within food which could explain weaker discrimination within food pictures. Perhaps, a feature-relevant AAT where the task instruction was based on a food category (e.g. sweet vs. not sweet) would lead to higher discriminability. Although it seems to be standard procedure in the AAT, visually similar object pictures might not be essential and some studies (Paslakis et al., 2016; Rohr et al., 2015) did not include them. Similar to the IAT, two separatable food groups could potentially be compared this way.

A major disadvantage of a feature-relevant task instruction lies in the need of participants to switch task instruction after the first test part which is not necessary for feature-irrelevant task instructions. Our results (presented in supplementary material 2) suggest that it was not easy for children to switch task instruction resulting in more errors and outliers in the second test part with a lower testing power as consequence. Furthermore, children's reaction time decreased over the course of the task probably due to training effects. Because approach bias represents the difference between the first and second test parts in the feature-relevant task setup, a systematic difference between children that started with one and children that started with the opposite task instruction occurred. In order to allow an accurate estimation larger training blocks might be necessary, or otherwise, the decrease in reaction time per test part needs to be corrected as done in the presented study. To our knowledge, this effect has not been investigated before. It could be particularly relevant in the application with children.

5. Conclusions

The present work aimed to apply the Approach avoidance task (AAT) to investigate children's automatic approach tendencies for the first time in a food-related context. We explored children's implicit approach bias to snacks differing in *sweetness* and *calorie* content and the link to explicit questionnaire-based results and preferences for a sugar vs. no-sugar added chocolate milk.

Children displayed a significant positive approach bias towards snack (food) pictures in general and a slightly negative approach bias to non-food pictures; we did not find significant differences in approach bias towards snack pictures with different levels of *sweetness* and *calorie* content.

Explicit expected liking discriminated among snacks varying in *sweetness* and *calorie* content, with most children liking *high sweetness* most, but individual differences regarding *calorie* content, some liked high caloric and others low caloric snacks more.

Individual differences in hunger state influenced children's implicit and explicit assessments; children who were hungry showed larger approach biases and expected liking ratings for high caloric snacks and a lower approach bias towards the high sweetness level, being more attracted to calorie-dense non-dessert food.

There were some common and some distinct patterns between the implicit and explicit results: around half of the children showed expected linking responses in line with their implicit bias responses (associated with high sweetness), while other children had distinct or even opposite patterns for both responses, suggesting that implicit bias measured via AAT and liking ratings may be representing different driving forces behind food behaviour.

Attitude subscales *craving for sweet food, using food as reward, affective attitude towards sweet food* and *cognitive attitude towards sweet food* were positively associated with children's explicit liking for high caloric snacks and were significantly associated with children's blind and informed preferences between a sugar and no-sugar added chocolate milk. Children's implicit approach bias was not significantly associated with their blind or informed preferences in the present study. Nevertheless, the potential link of approach bias to *sweetness* and *calorie* preference patterns cannot be dismissed by our study which focuses on preferences towards chocolate milk only. Future research should explore wider food choice scenarios, where more diverse, real choices are studied in a variety of foods, to assess food preference patterns in relation to implicit motivational tendencies.

CRediT authorship contribution statement

Martina Galler: Conceptualization, Methodology, Investigation, Writing – original draft, Visualization. **Emma Mikkelsen:** Conceptualization, Methodology, Investigation. **Tormod Næs:** Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision. **Kristian Hovde Liland:** Conceptualization, Investigation, Methodology, Writing – review & editing, Supervision. **Gastón Ares:** Conceptualization, Writing – original draft, Supervision. **Paula Varela:** Conceptualization, Methodology, Writing – original draft, Supervision.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodqual.2021.104416.

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Supplementary material 1: Test setup

Figure 1: Food pictures and visually matching non-food pictures from the "Food pics" database (Blechert et al., 2019) used for the Approach Avoidance task

Table 1

In the health subscale three questions were simplified after a pilot test as follows (back translated from Norwegian)

Original question as in (Roininen et al., 1999)	**Simplified question**
The healthiness of food has little impact on my food choices.	It is not important for me that the food I eat is healthy.
I am very particular about the healthiness of food I eat.	It is important for me that the food I eat is good for me.
I always follow a healthy and balanced diet.	I eat healthy and varied at all times.

Blechert, J., Lender, A., Polk, S., Busch, N. A., & Ohla, K. (2019, 2019-March-07). Food-Pics_Extended—An Image Database for Experimental Research on Eating and Appetite: Additional Images, Normative Ratings and an Updated Review [Original Research]. *Frontiers in Psychology, 10*(307). https://doi.org/10.3389/fpsyg.2019.00307

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Supplementary material 2: Approach avoidance task, data assessment

In order to assess the generated Approach avoidance task data by children, errors and outliers as well as reaction time structures were analysed (Table 1). It was of interest to investigate the existence of systematic differences between the first and the second *test part*, between *movement* of the joystick (pull or push) or between the two *picture categories* (food and non-food). Further *age* and *gender* differences were explored.

Error and outlier rates were lower in the first test part than in the second part where test instruction changed, indicating difficulty to switch the test response criterion in the second test part. Further, the joy stick *movement* "pull" resulted in less errors and outliers than the movement "push". Error and outlier rates were particularly high for the first response of each test part despite the preceding practice trials (Figure 1a).

Reaction time decreased in the second test part which could indicate a training effect over the test. There were no significant differences between the two *movements* (pull and push) and also not between the two *picture categories* (food and non-food). As seen for the error and outlier rates, the first responses of each test part had a high reaction time (Figure 1b).

Gender and *age* and their interaction were not significant regarding errors and outlier rates. Reaction time decreased according to *age*, older children reacted faster (Table 1 and Figure 1c). *Gender* and the interaction *gender x age* were not significant.

Table 1

The effect of test design factors as well as children's *age* and *gender* on the binary error and outlier variable was analysed with a mixed logistic regression with *child* as random nested in *age* x *gender*. The effect of test design factors as well as children's *age* and *gender* on the continuous reaction time variable was tested with a linear regression model with *child* as random nested in *age* x *gender*.

	Errors and/or outlier (binary yes/no) Mixed logistic regression				**Reaction time (ms)** Mixed linear regression				
	Estimate	Std. Error	z value	Pr(>|z|)	Estimate	Std. Error	df	t value	Pr(>|t|)
(Intercept)	-1.81	0.06	-30.68	**<0.001**	855.9	24.2	91.9	35.3	**<0.001**
Test part, 1 - 2	-0.31	0.02	-12.79	**<0.001**	10.6	2.9	11880	3.7	**<0.001**
Movement, pull - push	-0.06	0.02	-2.54	**0.011**	-4.6	2.9	11879	-1.6	0.110
Picture, food - non-food	-0.01	0.02	-0.60	0.546	-5.6	2.9	11879	-2.0	0.050
Age, 9 y. - 11 y.	0.05	0.06	0.82	0.415	82.1	26.9	92	3.1	**0.003**
Age, 10 y. - 11y.	-0.04	0.07	-0.55	0.582	8.4	29.4	92	0.3	0.777
Gender, boys - girls	0.09	0.06	1.52	0.129	13.4	24.2	92	0.6	0.582
Age, 9 y. - 11 y. x Gender, boys - girls	-0.03	0.06	-0.47	0.642	-10.7	26.9	92	-0.4	0.691
Age, 10 y. - 11y. x Gender, boys - girls	0.07	0.07	0.97	0.335	-37.1	29.4	912	-1.3	0.211

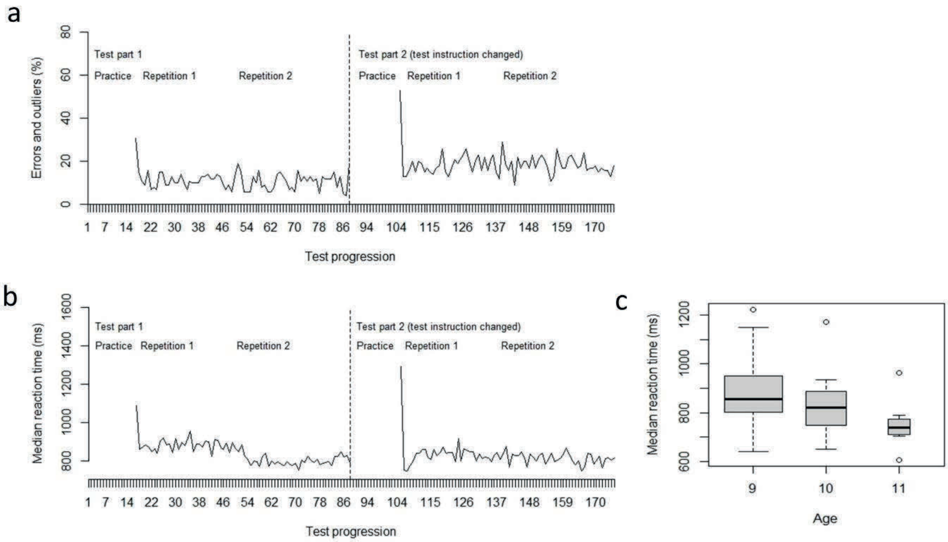

Figure 1 a: Ratio of errors and outliers along the AAT test progression. b: Median reaction time according to test progression (data points with errors and outliers were excluded). In Test part 2 the test instruction was switched (order of test instruction was balanced among children). Each Test part started with a practice trial of 16 pictures, followed by the measurement of 36 different pictures in two repetitions. c: Significant age effect on reaction time: 11-year-olds were faster then 9-year-olds.

Children's reaction times decreased over the course of the test (Table 1 and Figure 1b). As the approach bias represents the difference between the first and second test part, the order of test instruction children followed had an influence on their approach bias towards food and non-food. Children that started with the instruction "pull food and push non-food" in the first test part and "push food and pull non-food" in the second test part ended up with less positive approach biases for food and less negative approach biases for non-food than children who followed the opposite order (Table 2). The difference between food and non-food was only significant for the latter group (Table 3). Therefore, children's approach biases were adjusted by the estimate for reaction time difference between the two test parts extracted from Table 1 (= 10.6 ms) which is particularly important for the investigation in individual differences within the food category.

Table 2

Approach bias (AB) as influenced by the order of test instruction. The order of test instruction influenced approach bias of picture category (food, non-food). Children who followed the test instruction "push food and pull non-food" in the first test part, where reaction time was generally slower, ended up with larger approach biases for food and particularly a larger difference to non-food pictures than the other group. AB = Approach bias, RT = Reaction time

Order of test instruction	**Measurement during test**				**Approach bias calculation**	
	Test part 1: slower RT		Test part 2: faster RT		AB Food	AB Non-food
	Food	Non-food	Food	Non-food	RT push – RT pull	RT push – RT pull
Started with "Push food and pull non-food", N=52	RT push	RT pull	RT pull	RT push	Mean = 54.1 SD = 366.8	Mean = -39.8 SD = 395.3
Started with "Pull food and push non-food", N=47	RT pull	RT push	RT push	RT pull	Mean = 26.5 SD = 319.5	Mean = 4.8 SD = 315.7

Table 3

The effect of picture category on the continuous Approach bias variable was analysed with a mixed regression with *child* as random factor and the interaction between *picture category* and *child*.

Group of children	Picture category compared	Independent factors	DF	SS	MS	F-value	P-value
Started with “Push food and pull non-food”, N=52	18 food, 18 matching non-food	Picture category	1	3775625	3775625	13.05	**<0.0001**
		Child	51	9225640	180895	0.63	0.952
		Picture category x child	51	14757510	289363	2.07	**<0.0001**
		Error	1660	232203790	139882		
Started with “Pull food and push non-food”, N=46	18 food, 18 matching non-food	Picture category	1	145606	145606	0.40	0.520
		Child	45	3758416	83520	0.24	1.000
		Picture category x child	45	15543294	345407	3.59	**<0.0001**
		Error	1470	140696645	95712		
Entire group, AB based on RT where test parts were adjusted, N=98	18 food, 18 matching non-food	Picture category	1	2567194	2567194	8.21	**0.005**
		Child	97	13028124	134311	0.43	1.000
		Picture category x child	97	30343188	312816	2.63	**<0.0001**
		Error	3130	372900436	119138		-

Paper 4

In preparation

Capturing food-elicited emotions: facial decoding of children's implicit and explicit responses to tasted samples

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Abstract

Sensory and consumer research increasingly aims to gain direct input from children to study their eating behaviour. Advances in image processing and machine learning have brought forward opportunities for predictions of basic emotions via facial decoding, generating quantitative observational data.

The present study aimed to measure children's implicit and explicit basic emotions elicited by tasting, through the use of facial decoding and compare them to children's liking ratings in a case study with flavoured chocolate milk samples. Children aged 9-10 participated in the study (n=48). Six samples based on two DoE factors A*dded sugar* (yes / no) and *Surprise flavour* (peppermint / liquorice/ no added flavour) were tested. The software iMotions with the AFFDEX algorithm was used for facial decoding. For each sample, facial expression was measured immediately after tasting (implicit basic emotions). Then, children were asked to show a facial expression related to their feelings when they tasted the chocolate milk (explicit basic emotions) and rate their liking.

Implicit and explicit basic emotion likelihoods from facial decoding were correlated to liking regarding the factor *Surprise flavour*. As in previous studies, the measurement of implicit basic emotions discriminated samples according to negative emotions (anger and disgust) which had higher likelihoods in disliked samples with *Surprise flavour* (peppermint and liquorice). Facial decoding of explicit basic emotions presented the only measurement that discriminated samples additionally according to *Added sugar,* an advantage over liking ratings with the involved age group. The positive emotion joy as well as negative emotions (sadness, fear, anger, disgust and contempt) were significant. The results add to previous literature suggesting that the measurement of implicit emotions via facial decoding can be useful to study negative emotions while explicit basic emotions enhanced the discrimination of liked samples.

1. Introduction

Sensory and consumer research increasingly aims to gain direct input from children to study their eating behaviour (Laureati, Pagliarini, et al., 2015). The measurement of emotions is thought to add additional dimensions to liking ratings and by this, to improve the predictability of food choices (Gutjar et al., 2015). For tests with children, non-verbal questionnaire-based emotion measurements such as emojis have come into application presenting an easy and engaging way to study food experiences (Schouteten et al., 2019; Sick et al., 2020). However, depending on the age group involved, self-administered questionnaires can be cognitively challenging for children (Guinard, 2001). Further, social desirability effects can potentially bias self-reported results (Klesges et al., 2004). Therefore, indirect tests that do not rely on self-reporting have been suggested as less biased measurements (Köster, 2009; Laureati, Pagliarini, et al., 2015).

In recent years, advances in image processing and machine learning have brought forward opportunities to predicting basic emotions via algorithms from video recordings which could make such measurements more efficient. Ekman and Heider (1988) defined seven basic emotions, joy, anger, fear, sadness, surprise, disgust and contempt as universally recognizable based on facial expressions. Traditionally, basic emotions have been classified via the facial action coding system (FACS) performed by highly trained coders. A broad range of consumer studies have used FACS to measure consumer's affective experiences with products (Clark et al., 2020). Such measurements could be particularly interesting with children. Several observation studies with infants could associate specific facial expressions to different basic tastes and odours (Forestell & Mennella, 2017; Rosenstein & Oster, 1988; Soussignan et al., 1997; Steiner et al., 2001). Further, similar patterns were found in adults, although some deviations linked to socialization occurred (Weiland et al., 2010). The interpretation of facial expressions as emotions are challenged by constructed emotion theorists (Barrett, 2004, 2006a, 2006b; Barrett, 2016; Barrett et al., 2011) that do not consider emotions to be nature-given but rather shaped by culture. Facial expressions differ between individuals, their interpretation is highly dependent on context as well as on the interpreter (Barrett, 2006b; Barrett et al., 2011). Facial decoding via algorithms reflects this uncertainty by predicting a likelihood for each basic emotion to be present rather than a classification. To account for individual differences, machine learning algorithms are trained on a wide variety of faces.

If participants are not aware of the time point when their facial expression is measured during an experiment or video recording, the study of these images can be considered as measurement of implicit automatic responses of which participants might not even be consciously aware off. Previous food related studies in laboratory settings indicated that implicit facial decoding mainly detected negative emotions linked to disliked samples, while liked samples provoked rather neutral faces (Danner et al., 2014; Kostyra et al., 2016; Pedersen et al., 2021), this was also observed in a small sample of school-aged children via human decoders (Zeinstra et al., 2009). Danner et al. (2014) used explicit facial decoding "make a face" as additional measurement with adults which yielded a higher food sample discrimination also for the positive emotion "joy". Danner et al. (2014) further noted that some people were generally more expressive than others, the "poker faces", that showed no emotions which might hamper product testing via facial decoding.

The present study aimed to measure children's (9-10 y. o.) implicit and explicit basic emotions elicited by tasting, through the use of facial decoding, and compare them to children's liking ratings in a case study with flavoured chocolate milk samples.

2. Materials and Methods

The study was conducted at Vitenparken Campus Ås within a science outreach program, which is offered to school classes in the Akershus region. Children visited the science centre with their school classes and teachers. They had different science lectures, activities, and exhibitions throughout the day and among those, the current study. The test was performed by one child at a time and a researcher was present for an initial instruction and assistance. Participants also completed a packaging evaluation where their eyes were tracked and filled in an attitude questionnaire (results not reported) resulting in a test length of approximately 20 minutes.

2.1. Participants

A total of 48 children with balanced gender ratio (47 % girls) between 9 and 10 years old participated. A protocol of the study was presented to the Norwegian Centre for Research Data (NSD), reference 476380. Prior to the test, parents were informed about the experiment via the school communication app, filled in a short questionnaire about food intolerances or allergies and gave consent through an electronical form. All children provided oral assent. They were informed that they could leave the test at any time without consequences. As token of appreciation for their participation children received a chocolate milk pack after the test.

2.2. Samples

Six chocolate milk samples, modified with added flavour, to be different enough from a sensory perspective, were developed in collaboration with product developers at the Norwegian milk producer Tine SA. Samples followed a design of experiment with two factors *Added sugar* and *Surprise flavour* (Table 2). For the factor *Added sugar*, two commercially available chocolate milks targeted at children were used (Litago® Original chocolate milk with added sugar and Litago®Light Chocolate milk without added sugar). The no sugar added version was optimized regarding sweetness through lactose hydrolysis as well as regarding bitterness by substitution for a milder cocoa powder. For the second factor, *Surprise flavour*, either liquorice or peppermint aroma were added. The peppermint and liquorice aromas were chosen as these two flavours are usually used in chocolate products, so they would match the sensory profile, but no chocolate milk with those was available in the Norwegian market at the time of the study. The idea was to create a surprising sensory experience that could be hopefully reflected in the emotional expressions displayed by children when tasting. Further, it was of interest, if flavour addition could compensate the reduced sweetness level in *No added sugar*.
The chocolate milk samples were mixed the same day of testing and poured just before serving.

As a warm-up sample to test and understand test instructions, plain milk was served. Samples were served in black plastic cups that masked any slight colour differences between the samples. Cups were coded with angular geometric symbols displayed in Table 2 that facilitated self-serving of samples by children during the test.

Samples were randomized across participants in two blocks. First, the two samples without flavour, followed by samples with flavour to prevent carry-over effects of flavoured to non-flavoured samples (Table 1).

Table 1
Chocolate milk sample design with design of experiment factors

Sample code	Sample name	Added sugar	Surprise flavour	Serving block
□	**S**	yes	-	1
◆	**NS**	no	-	1
*	**L-S**	yes	Liquorice	2
▭	**L-NS**	no	Liquorice	2
+	**M-S**	yes	Peppermint	2
△	**M-NS**	no	Peppermint	2

2.3. Test procedure

Sample tasting was performed in a closed room to avoid distractions. The researcher explained the setting and assisted the tasting of the warm-up sample according to questionnaire instructions (Figure 1). Then, the researcher sat behind a partition wall to not distract the child during the test to avoid influencing their facial expressions.

The test flow is shown in Figure 1 as screenshots of the instructions the children received : 1) instruction screen: find sample and show it to the camera; 2) a short instruction film was shown so the children would taste all samples with the same speed; 3) a fixation point was shown in the middle of the screen, where the implicit facial reaction to the tasted sample was measured (children were instructed by the researcher during the warm-up tasting to look at the fixation point) - after 13 seconds it automatically forwarded to the next screen; 4) instruction screen: “Show with your face how you feel about the tasted sample” for the explicit facial decoding, 5) liking rating via 7-point hedonic scale, 6) instruction screen: mouth rinsing with water

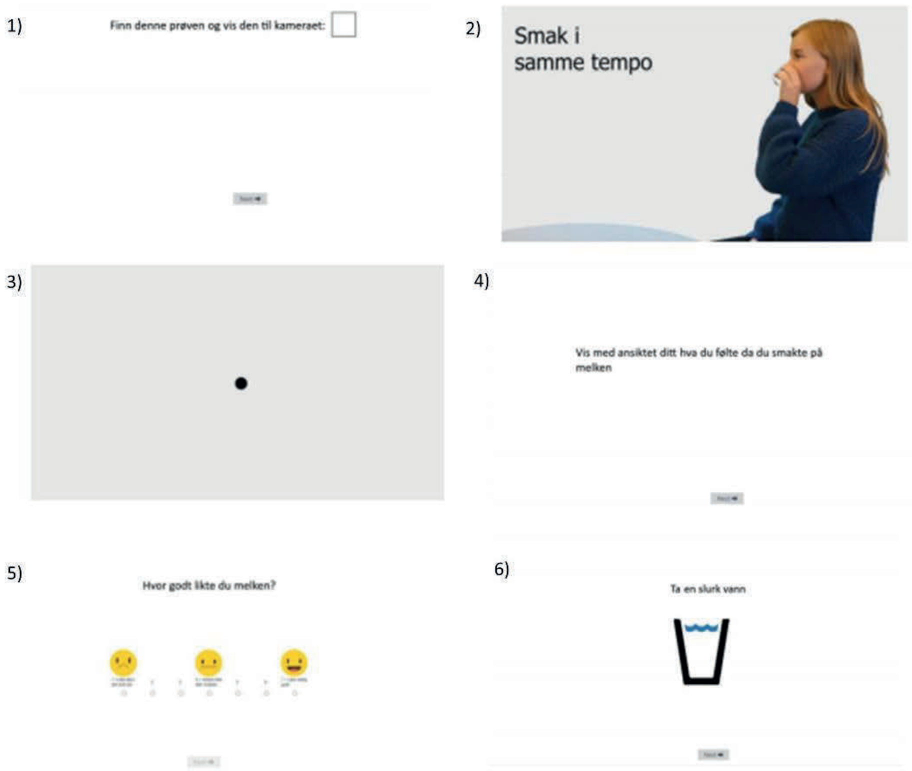

Figure 1: Screenshots of the sample tasting questionnaire: 1) find sample and show it to the camera, 2) Watch instruction film and taste sample at the same tempo, 3) fixation point where implicit facial reaction to tasted sample was measured (children were instructed by the researcher during the warm-up tasting to look at the fixation point), 4) instruction to show with the face how the sample tasted, 5) liking rating, 6) neutralizing taste with water

2.3.1. Facial decoding

Participants' faces were recorded using a Logitech C920 Hd Pro webcam that was placed on top of the PC screen. The AFFDEX SDK 4.0 (Affectiva Inc., Waltham, USA) system implemented in the iMotions 8.1 platform was used to classify videorecorded movements of key face features (i.e., facial landmarks such as brows, eyes, and lips) of participants into basic emotions. The coding system allows the classification of seven basic emotions, joy, surprise, anger, fear, disgust, contempt and sadness. Each basic emotion was quantified as likelihood ranging from 0 (not expressed) to 100 (certainly expressed).

The time frame of measurement after sample ingestion for implicit as well as explicit facial expression measurements were annotated manually by the researcher that collected the data. For the implicit measurement the time interval varied between 6-13 seconds depending on the time point that the child moved down the cup from their face after drinking. For the extrinsic part a constant time interval of 1 second was annotated. Within the annotated time frame, the maximal probability of each basic emotion was extracted and used for subsequent data analysis.

2.3.2. Liking rating

Children rated their expected liking on a 7-point hedonic scale with smiley faces as well as text at 1 = did not like at all, 4 = neither liked nor disliked, 7 = liked very much) as anchor points (Figure 1).

2.5. Data analysis

All analyses were performed in R, version 4.0.4. Significance was determined based on a significance of 5%. The R package “mixlm” (Hovde Liland, 2019) was used for linear mixed ANOVAs and post-hoc tests of significant fixed effects. Further, the R package “FactoMineR” (Lê et al., 2008) was used to perform a multiple factor analysis (MFA) as well as a principal component analysis (PCA).

One child was excluded from the data analysis as it did not understand the test instruction, resulting in 47 answers considered for the data analysis. Children’s liking ratings, implicit and explicit basic emotions likelihoods were analysed as dependent variables via mixed ANOVAs with sample as fixed and child as random variable. Further, measurements were analysed regarding design of experiment factors of the samples, *Added sugar* and *Surprise flavour* via mixed ANOVAs with *Added sugar* and *Surprise flavour* well as their interaction as fixed main and child as random factors. Tukey tests were performed as post hoc analysis of significant fixed effects to determine the significance levels.

Average liking, and average implicit and explicit basic emotions that discriminated samples significantly were overlayed as three blocks by an MFA with samples as rows and measurement variables as standardized columns.

To investigate the correlation of basic emotion likelihoods and to compare children accordingly, a PCA with basic emotion likelihoods averaged over the six tasted samples as unstandardized columns and children as rows were performed for the implicit and explicit facial decoding separately.

3. Results

3.1. Explicit liking rating

Significant differences in children’s liking ratings of the samples were found (Table 2). Children’s ratings indicated a higher liking of the samples without *Surprise flavour* as compared to those with *Surprise flavour*. As shown in Figure 2, children rejected the samples with the surprise flavour, which was stronger for liquorice compared to peppermint. No significant differences in liking were found according to *Added sugar*.

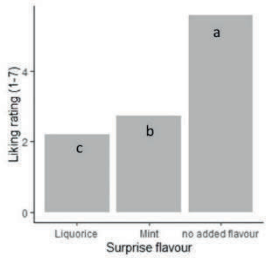

Figure 2: Liking rating for the different design of experiment factors. Significance levels are marked with letters.

3.2. Implicit facial decoding

Joy, disgust and contempt were the implicit basic emotions with the highest average likelihood (32-37 %), whereas fear had the lowest likelihood (6 %) (Table 2 and Figure 3). Implicit facial decoding discriminated samples regarding two out of seven basic emotions: anger and disgust. Both emotions discriminated samples based on the factor *Surprise flavour*. The addition of the *Surprise flavour*, both peppermint and liquorice, increased the likelihood of children expressing the basic emotions anger and disgust (Figure 4).

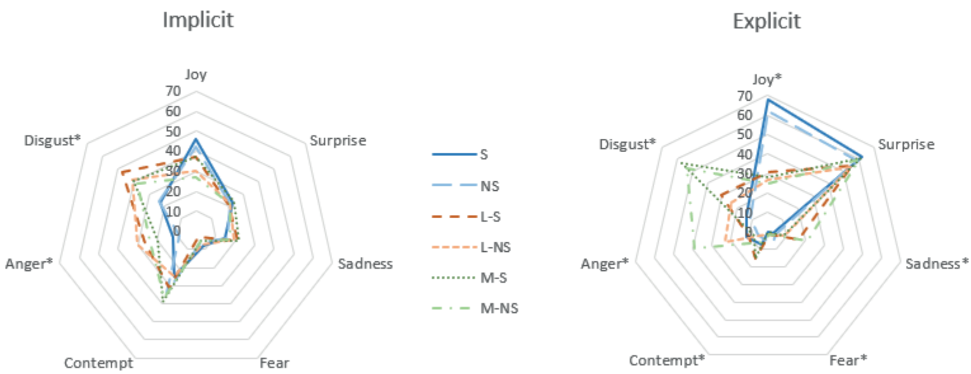

Figure 3: Implicit and explicit facial decoding predicting basic emotional responses (average likelihoods (%)) to samples (**S** = Sugar added, **NS** = No sugar added, **L-S** = Liquorice, sugar added, **L-NS** = Liquorice, no sugar added, **M-S** = Peppermint, sugar added, **M-NS** = Peppermint, no sugar added). * marks basic emotions that discriminated samples significantly.

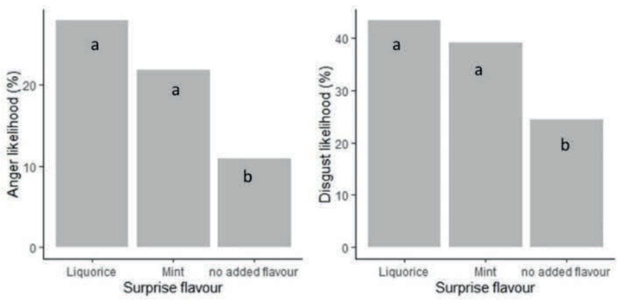

Figure 4: Implicit basic emotions as measured by face decoding for the different design of experiment factors. Significance levels are marked with letters.

3.3. Explicit facial decoding

Surprise, joy and disgust were the explicit basic emotions with the highest likelihood (32-59 %), fear and contempt the lowest (1-8 %) (Table 2 and Figure 3). Explicit facial decoding discriminated the samples regarding six out of seven basic emotions. Only the emotion surprise was not significant to discriminate among the chocolate milks. The emotions joy, sadness, anger and disgust discriminated samples regarding *Surprise flavour* (Figure 5). The likelihood for the explicit basic emotion joy was higher for the samples without *Surprise flavour*. Sadness, anger and disgust were higher in the samples with *Surprise flavour*, peppermint in particular. Fear, contempt and anger discriminated samples regarding *Added sugar*. The likelihood of fear and anger was higher in samples without *Added sugar*, the likelihood of contempt was higher in the samples with *Added sugar*. Sadness, fear and anger were also significant for the interaction between the two factors *Added sugar* and *Surprise flavour* (average likelihoods and significance levels are displayed in Figure 5).

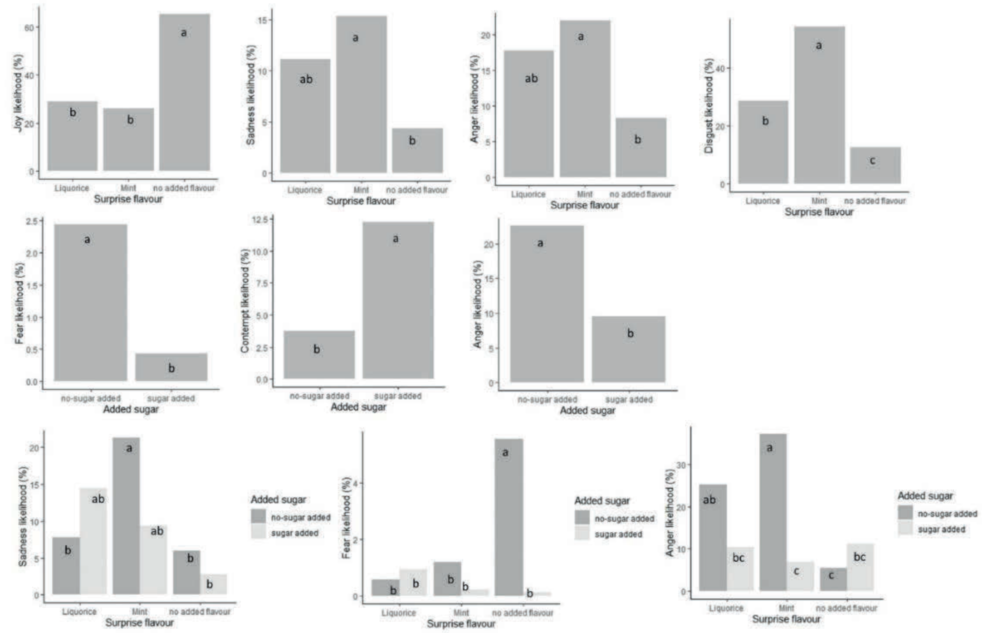

Figure 5: Explicit basic emotions, as measures by face decoding, for the different design of experiment factors. Significance levels are marked with letters.

Table 2
Mean values of liking ratings (1-7-point scale) and basic implicit and explicit emotions measured by face decoding (maximal likelihood estimation). Significance levels (as per Mixed ANOVAs) are indicated with superscripts next to mean values.

			Mean values of samples						**p-values of Mixed ANOVAs**		**Significant design of experiment factors***
		Total	**S**	**NS**	**L-S**	**L-NS**	**M-S**	**M-NS**	**Samples**	**Children**	
Liking rating	Liking	3.5	5.8 [a]	5.3 [a]	2.1 [b]	2.2 [b]	2.7 [b]	2.6 [b]	**<0.001**	**<0.001**	*Surprise flavour*
Implicit emotions	Joy	37	46	42	37	30	37	27	0.234	**<0.001**	-
	Surprise	22	23	22	21	22	24	22	0.983	**<0.001**	-
	Sadness	18	15	16	21	19	22	17	0.586	**<0.001**	-
	Fear	6	8	6	3	7	5	5	0.673	**<0.001**	-
	Contempt	32	25 [b]	34 [b]	31 [a]	25 [ab]	39 [ab]	37 [ab]	0.393	**<0.001**	-
	Anger	20	12 [bc]	9 [c]	26 [ab]	30 [a]	20 [abc]	24 [abc]	**<0.001**	**<0.001**	*Surprise flavour*
	Disgust	36	23	24	47	41	40	38	**0.001**	**<0.001**	*Surprise flavour*
Explicit emotions	Joy	40	68 [a]	62 [a]	31 [b]	27 [b]	28 [b]	25 [b]	**< 0.001**	**<0.001**	*Surprise flavour*
	Surprise	59	62	59	55	54	61	60	0.322	**<0.001**	-
	Sadness	10	3 [c]	4 [bc]	16 [ab]	9 [abc]	8 [bc]	21 [a]	**<0.001**	**<0.001**	*Surprise flavour, Added sugar x Surprise flavour*
	Fear	1	0 [b]	6 [a]	1 [b]	1 [b]	0 [b]	1 [b]	**0.002**	0.648	*Added sugar, Added sugar x Surprise flavour*
	Contempt	8	7 [a]	4 [a]	15 [a]	1 [a]	15 [a]	6 [a]	**0.017**	**0.046**	*Added sugar*
	Anger	16	11 [bc]	5 [c]	10 [bc]	23 [ab]	7 [bc]	39 [a]	**<0.001**	**0.020**	*Added sugar, Surprise flavour, Added sugar x Surprise flavour*
	Disgust	32	14 [b]	12 [b]	31 [b]	24 [b]	57 [a]	53 [a]	**<0.001**	**<0.001**	*Surprise flavour*

S = Sugar added, **NS** = No sugar added, **L-S** = Liquorice, sugar added, **L-NS** = Liquorice, no sugar added, **M-S** = Peppermint, sugar added, **M-NS** = Peppermint, no sugar added *Significance of design of experiment factors determined by additional mixed models: detailed results are presented in Supplementary material.

3.4. Relationship between liking ratings and implicit and explicit emotions measured by facial decoding

Implicit and explicit basic emotions and liking averages per sample were overlayed by means of multiple factor analysis (Figure 6). Implicit and explicit basic emotions were correlated to explicit liking rating in the first dimension, explaining 71% of variance. This dimension discriminated samples based on *Surprise flavour* (no added flavour vs. Peppermint or Liquorice flavour). For implicit, as well as explicit facial decoding, the basic emotions anger and disgust were negatively correlated to liking and associated with the added flavours Peppermint and Liquorice. For the explicit emotions by facial decoding, joy was positively correlated to liking and associated with the *no added* flavour samples. Explicit emotions further discriminated samples regarding *Added sugar* in the second dimension explaining 13% of variance. *Added sugar* was associated to the emotion contempt. *Added flavour without added sugar* was associated with anger. No *Surprise flavour* and no *Added sugar* were associated with fear.

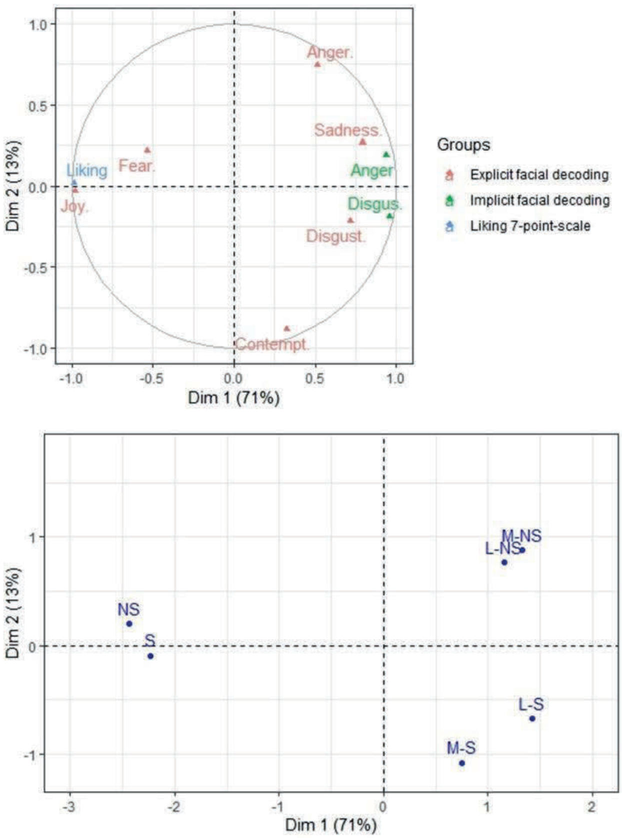

Figure 6: Multiple factor analysis overlaying implicit and explicit basic emotions that discriminated samples significantly as well as liking ratings. All variables were standardized. Top: Variable plot, bottom: product plot.

3.5. Comparison of children's basic emotion likelihoods

The first two components of a PCA on unstandardized basic emotions likelihoods summed up over the six samples revealed similar patterns for the implicit and explicit facial decoding (Figure 7). Their likelihoods were correlated in the first component, explaining 26% of variability for the implicit measurement and 65% of variability in the explicit measurement. There were children whose predicted basic emotion likelihoods were generally lower, previously classified as "poker faces" by Danner et al. (2014). The second component of the PCA split children who had higher likelihoods of negative basic emotions and children that had higher likelihoods of positive basic emotions. However, the implicit measurement contempt correlated with the emotions joy and surprise. The comparison of implicit and explicit classification into expressive vs. poker faces (PC1) and positive vs. negative emotions (PC2) did not show a clear association between the two measurements (Table 3). For example, taking child number 29 in the plots as example (Figure 6), they were "poker face" in the implicit measurement while "expressive" in the explicit.

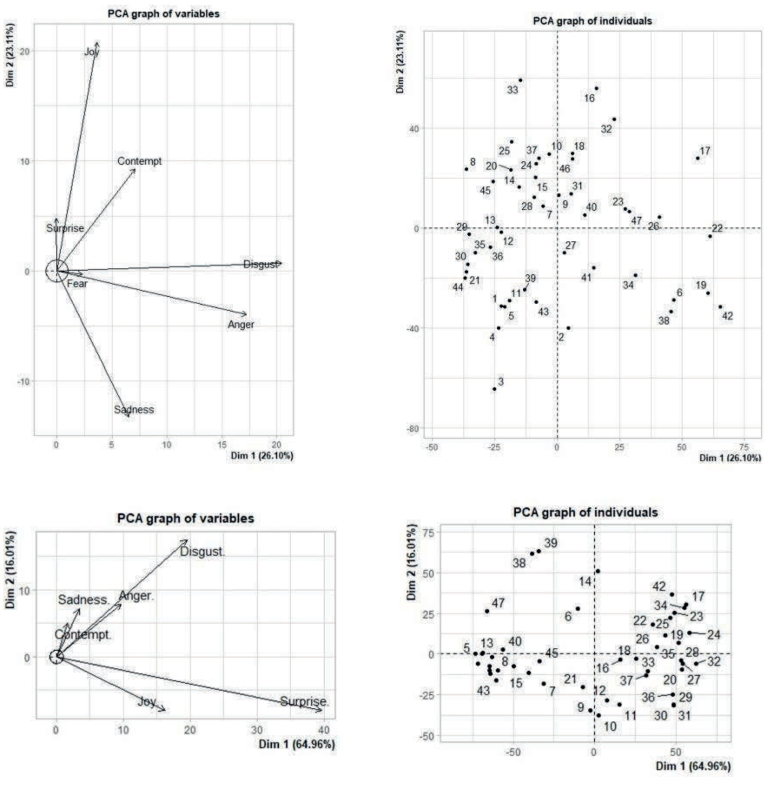

Figure 7: Principal component analysis of children's likelihood of an emotion summed up over the six samples with emotions as unstandardized variables and children as individuals. Based on the plot, children were split into poker faces (left side) and expressive faces (right side). Top: implicit basic emotions, bottom: explicit basic emotions

Table 3

Number of children’ facial expressions classified as poker vs. expressive in the implicit and explicit measurement without significant link between implicit and explicit (Chi-squared test).

PC1				**PC2**			
		Implicit				**Implicit**	
		Poker face	Expressive face			Positive	Negative
Explicit	Poker face	13	8	**Explicit**	Positive	14	14
	Expressive face	14	12		Negative	10	9

4. Discussion

4.1. Comparison between facial decoding of implicit and explicit emotions

Facial decoding discriminated samples more with explicit compared to implicit basic emotions. Positive as well as negative explicit emotions were significant, in line with the study by Danner et al. (2014) with adults. Explicit facial expressions are more prototypical while implicit facial expressions are more natural. Stockli et al. (2018), who validated the accuracy of facial decoding by the iMotions software used in the present study, found a low accuracy for natural expressions as compared to prototypical ones which might explain the lower discrimination.

Facial decoding of implicit as well as explicit emotions discriminated children based on their overall degree of expressiveness (poker vs. expressive), as well as their tendency for more positive or negative basic emotions. However, the implicit and explicit measurements produced different classifications. Stockli et al. (2018) highlighted that some emotions are underpredicted and some overpredicted, particularly for natural facial expressions which are more likely to appear during the measurement of implicit emotions. Further, social desirability, introspection aspects as well as personality type might have influenced facial decoding of explicit emotions resulting in different patterns. A meta-analysis found that emotional expressiveness and extraversion were related, but that results differed between self-reported and behavioural emotional expressiveness measurements (Riggio & Riggio, 2002).

4.2. Emotions measured by facial decoding vs. liking ratings

Results showed that facial decoding of implicit emotions discriminated disliked samples based on a higher likelihood for anger and disgust. These results add to previous studies in laboratory settings that measured negative basic emotions for disliked samples but did not detect positive emotions linked to liked samples (Danner et al., 2014; Kostyra et al., 2016; Pedersen et al., 2021; Zeinstra et al., 2009). The disliked samples were not discriminated by implicit facial decoding while they were by liking ratings. Thus, in the present case study, liking ratings were more sensitive than implicit emotions measurement.

Facial decoding of explicit emotions showed a higher discrimination regarding the design of experiment factors than liking ratings, discriminating samples based on *Surprise flavour,* as well as on *Added sugar*. Explicit emotions revealed the same pattern for the discrimination of samples with and without *Surprise flavour* as liking ratings did, but with a different pattern for the samples added with *Surprise flavour* (peppermint and liquorice). Children’s liking ratings indicated that they disliked the liquorice flavour more than the peppermint flavour. However, the negative emotions sadness, anger and disgust showed the opposite pattern, as they displayed larger likelihoods for peppermint added samples than for liquorice.

In the study by Danner et al. (2014) with adults, explicit emotions measured by facial decoding correlated more to liking ratings than implicit ones, which they linked to the explicit nature of both measurement. In the present study with children, explicit facial decoding was in turn more discriminative than liking ratings which was not the case in Danner et al. (2014). In another study by the authors (Galler et al, submitted), on the same chocolate milk samples, a paired preference task between the sugar and non-sugar added chocolate milks (without *Surprise flavour*) showed that the sugar added chocolate version was significantly preferred, suggesting that explicit basic emotions may have helped to predict food choice more accurately than the liking ratings collected in the present study. Facial decoding of explicit emotions might be particularly well suited for product testing with children, as the making of explicit expressions may be part of their games, so they see it as more natural, or they may be less shy than adults when presented with these types of exercises. Alternatively, children's liking ratings could also be less discriminative than adults.

4.3. Methodological considerations and future research

As in previous studies in laboratory settings the measurement of implicit basic emotions was only useful to study disliking, which might be not as useful for product optimization testing of pleasurable food. Implicit facial decoding could however be useful to investigate in food-elicited disgust which is highly relevant to study food rejection linked to picky/fussy eating or food neophobia (e.g. Lafraire et al., 2016) in children. Further, our study indicated that explicit facial decoding could offer an advantage over liking ratings which opens the door for further studies. Explicit facial expressions might, to a certain extent, be relevant in real life eating situations where expressions are used to communicate with others. In this sense, Köster and Mojet (2015) highlighted that situational factors, such as eating alone vs. eating with family are closely linked to emotions and that emotion tests in laboratories might fail to measure emotions of ecologic validity.

There is limited facial decoding research where food samples are tasted, particularly with children. It is particularly challenging to measure facial expressions when samples are tasted as the hands that move the samples to the mouth can cover part of the face. In the presented study, challenges were overcome by the use of a video instruction to enable a standardized one sip tasting, in order to ensure that the cup did not cover the face after the tasting which would obstruct the measurement. This case focused on liquid samples only, further research should also focus on different types of foods, as well as more natural eating situations which may call for different test protocols and evaluation methods. Facial decoding might also be a valuable measurement for home-use tests where testers typically sit in front of a computer screen by themselves.

It remains unclear, what the measured basic emotions mean in an eating context and how accurate the predictions are. In an eating context, a sad face can for example mean profound pleasure (Barrett, 2020). To shed light on the meaning of predicted basic emotions in the eating context, it is of interest how basic emotion classifications relate to self-reported emotions although such measurements are explicit and require introspection ability by participants. A recent study measured implicit basic emotions via the AFFDEX algorithm as well as self-reported emotions via the EsSense Profile®, but did not compare the measurements (Mehta et al., 2021).

Last but not least, the focus on individual differences might be highly relevant for the measurement of emotions (Köster & Mojet, 2015). Future studies with larger sample sizes should further investigate individual differences in basic emotion likelihoods linking them to preference patterns, food related attitudes such as food neophobia, personality measurements and demographics.

5. Conclusions

The presented study suggests a procedure to perform facial decoding with children in tasting experiments and offers first insights into the applicability of such measurements for the understanding of hedonic and emotional reactions to foods.

Implicit and explicit emotion measurements by facial decoding were successful with 9 to 10 year old children, enabling a non-verbal sample evaluation. The results add to previous literature suggesting that the measurement of implicit emotions via facial decoding can be useful to study negative food-elicited emotions, e.g. disgust, elicited by disliked samples. Explicit emotions measurement by facial decoding was also suitable to measure negative emotions but enhanced the discrimination of liked samples. Sample discrimination of explicit facial decoding was in fact higher than liking ratings. Further research is needed to assess facial decoding prediction accuracy for food choice, the meaning of food-elicited basic emotions from facial decoding in the eating context as well as individual differences.

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Author statement

Martina Galler: Conceptualization, Methodology, Investigation, Writing – Original draft, Visualization. **Åse Riseng Grendstad**: Conceptualization, Methodology, Investigation, Writing – review. **Gastón Ares**: Conceptualization, Writing – Original draft and review, Supervision. **Paula Varela**: Conceptualization, Methodology, Writing – Original draft and review, Supervision

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Supplementary material

Table 1

Mixed ANOVAs with DoE factors as main and interaction as fixed, child as well as child in interaction with DoE factors as random variables.

		Added sugar	Surprise flavour	Added sugar x Surprise flavour	Child
Explicit rating (1-7-point scale)	Liking	0.372	**<0.001**	0.350	**<0.001**
Implicit facial decoding (maximal likelihood estimation)	Joy	0.261	0.051	0.795	**<0.001**
	Surprise	0.883	0.902	0.843	**<0.001**
	Sadness	0.523	0.424	0.544	**<0.001**
	Fear	0.917	0.503	0.508	**<0.001**
	Contempt	0.870	0.052	0.463	**<0.001**
	Anger	0.755	**<0.001**	0.599	**<0.001**
	Disgust	0.394	**<0.001**	0.877	**<0.001**
Explicit facial decoding (maximal likelihood estimation)	Joy	0.380	**<0.001**	0.982	**<0.001**
	Surprise	0.469	0.077	0.935	**<0.001**
	Sadness	0.264	**0.002**	**0.012**	**<0.001**
	Fear	**0.020**	0.072	**0.017**	0.658
	Contempt	**0.002**	0.328	0.288	**0.046**
	Anger	**<0.001**	**0.004**	**<0.001**	**0.024**
	Disgust	0.281	**<0.001**	0.912	**<0.001**

PAPER 5

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How children approach a CATA test influences the outcome. Insights on ticking styles from two case studies with 6–9-year old children

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ABSTRACT

Due to its simplicity, Check-all-that-apply (CATA) is a promising method for consumer studies with children to generate sensory and other descriptions of samples, and to find their drivers of liking. This paper explores how children's approach to the CATA test influences the outcome, based on two case studies that illustrate suitable setups for CATA tests with children of the age group 6–9. The children's approach to the CATA task was described with ticking style indicators based on which three ticking style groups were defined. One group ticked only a few attributes probably due to cognitive limitations, e.g. lack of reading skills, limited vocabulary or ability to focus on the task. The second group gradually increased their number of ticked attributes per sample over the test, while the third subgroup ticked a steady number of attributes throughout the test. The two latter groups are likely to represent different test strategies: one using the CATA list relatively to the sample space, and one using the CATA list as in a more absolute way. Analysis regarding data validity assessed by the detection of pre-defined Design of Experiment (DoE) sample differences and the alignment to a trained panel using Quantitative Descriptive Analysis (QDA) revealed that ticking style played a crucial role. This study shows the importance of analysing "ticking style" as a validation strategy for CATA tests run with children and as a tool to gain insights into underlying test strategies.

1. Introduction

Rapid sensory methods such as Check-all-that-apply (CATA) and Projective Mapping are now used in a broad range of applications, both in research and industry (Delarue, Lawlor, & Rogeaux, 2015; Varela & Ares, 2012). These methods can produce similar results as traditional descriptive methods with the advantage that they are more flexible and less time consuming. In their review, Varela and Ares (2012) describe how the emergence of rapid methods has blurred the line between sensory and consumer studies. Rapid methods have been validated both in studies with trained panellists (Dehlholm, Brockhoff, Meinert, Aaslyng, & Bredie, 2012) and with consumers (Ares, Barreiro, Deliza, Giménez, & Gámbaro, 2010; Bruzzone, Ares, & Giménez, 2012; Dooley, Lee, & Meullenet, 2010; Jaeger et al., 2013). As validation, they mainly used the comparison to results generated with traditional descriptive methods. Jaeger, Chheang, Yin, Bava, Gimenez, Vidal, and Ares (2013) evaluated the within-assessor reproducibility of several CATA datasets with repetitions generated by consumers.

Many rapid methods are simple to perform and therefore promising to use in consumer studies with special populations such as children. In recent years, various applications of rapid methods with children have been published. Daltoe, Breda, Belusso, Nogueira, Rodrigues, Fiszman, and Varela (2017) used projective mapping with food stickers to understand the perception of fish of different age groups. Varela and Salvador (2014) concluded that children from the age of five years old could perform a structured sorting task with images. The most common rapid method used with children has, however, been the CATA method. Researchers used the CATA method with sensory attributes (Cardinal, Zamora, Chambers, Carbonell Barrachina, & Hough, 2015; Laureati, Cattaneo, Lavelli, Bergamaschi, Riso, & Pagliarini, 2017; Lima, Ares, & Deliza, 2018; Schouteten, De Steur, Lagast, De Pelsmaeker, & Gellynck, 2017), emotional attributes (De Pelsmaeker, Schouteten, & Gellynck, 2013; Schouteten, De Steur, Lagast, De Pelsmaeker, & Gellynck, 2017; Schouteten, Verwaeren, Gellynck, & Almli, 2019; Schouteten, Verwaeren, Lagast, Gellynck, & De Steur, 2018) and hedonic attributes (Yoo, Machín, Arrua, Antunez, Vidal, Gimenez, Curutchet, & Ares, 2017) to investigate children's perception and their drivers of liking.

In their review about sensory testing with children, Laureati, Pagliarini, Toschi, and Monteleone (2015) highlighted the importance of adapting test protocols to the cognitive level of the targeted age

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group to ensure that the results reflect the actual perception, not the cognitive limitations of understanding the task. One such limitation could be difficulties to understand the words of the CATA list. To avoid this potential issue, Laureati, Cattaneo, Lavelli, Bergamaschi, Riso, and Pagliarini (2017) and Schouteten, De Steur, Lagast, De Pelsmaeker, and Gellynck (2017) generated a CATA list with a panel of children while Lima, Ares, and Deliza (2018) did a pilot study to test if the children understood the CATA list.

How to evaluate the suitability of a test protocol for the respective age group regarding the validity of results is still a rather unexplored area. Schouteten, De Steur, Lagast, De Pelsmaeker, and Gellynck (2017) showed that children were able to discriminate samples with the CATA method. Laureati, Cattaneo, Lavelli, Bergamaschi, Riso, and Pagliarini (2017) and Lima, Ares, and Deliza (2018) could further show that predefined sample differences were detected. Cardinal, Zamora, Chambers, Carbonell Barrachina, and Hough (2015) and Lima, Ares, and Deliza (2018) compared children's discrimination capability to adults. To the authors' knowledge, no one has compared sensory profiling by children to a trained panel which is still the "golden standard" regarding the objectivity of sensory descriptive results. In their recent book, Næs, Varela, and Berget (2018) suggested the analysis of ticking style to understand how consumers use the CATA list which could potentially be used to study how children approach the test.

The objective of this paper is to explore the analysis of ticking style as a way of validating CATA testing with 6–9-year-old children. We investigate children's ticking style in two case studies, one on bread and the other on fruit smoothies. Further, based on the practical experiences and data analysis findings in each of the studies, we draw practical recommendations for conducting CATA tests with children.

2. Materials & methods

The two case studies, Bread and Smoothie, illustrate how a CATA test with children of the age group 6–9 can be set up, the first (Bread) conducted with experimenter assistance and the second (Smoothie) designed to ensure the autonomy of the children during the test. We defined three ticking style indicators to describe and group the children based on their usage of the CATA list: number of ticks, standard deviation of the number of ticks per sample, and number of different attributes used in the test. Then we analysed data validity regarding detection of sample differences based on the Design of Experiment (DoE) and regarding similarity to the sensory description of a trained profile panel by Quantitative Descriptive Analysis (QDA).

2.1. Samples

Bread and smoothie represent food types that are typically consumed by Norwegian children, displaying a high familiarity and acceptance. The samples in both case studies were developed to vary systematically in their sensory profiles based on a 2^3 factorial design, resulting in 8 different samples. Each factor covered a different sensory modality (*Darkness*, *Coarseness* and *Saltiness* for Bread; *Colour intensity*, *Thickness* and *Acidity* for Smoothie; Table 1). The bread samples were baked at the cereal pilot plant at Nofima, based on a non-commercial recipe (Figure S.1 in the supplementary material shows the visual differences between the bread samples). Samples were cut in circular shapes with a cookie cutter (3.7 cm diameter, 1.1. cm thickness). Samples were served within the same day of the baking and stored in plastic bags after cutting in order to prevent drying. The smoothie samples were prepared in lab scale by a commercial partner, using one of their commercial smoothies as a base. The base smoothie contained 100% fruit juice of raspberry, blueberry, strawberry, banana, apple and orange and naturally displayed a red colour. For the test, smoothies were warmed to room temperature shaken prior to pouring into cups containing approximately 25 ml each.

2.2. Consumer test with 6 to 9-year-old children

Three school grades from local schools in the Akershus county (Norway) participated in the consumer tests. Both studies were run in the respective schools and each school participated in one study only. The majority of the children were between 7 and 9-years-old. However, as the school grade is based on the year of birth in Norway, some 6-year-old children participated in the test as well. Parental informed consent forms, including allergy information, were collected before the tests. Children gave their informed assent to participate and were informed they could leave the test at any point. The data collection followed the ethical recommendations from the Norwegian Centre for Research Data.

2.2.1. Bread test

The check-all-that-apply (CATA) list was established by researchers based on the main sample properties as described by a trained panel. They defined ten attributes (Light colour, Dark colour, Not grainy, Grainy, Easy to chew, Hard to chew, Not coarse, Coarse, No salty taste, Salty taste). In each case, two attributes stretched the same dimension as antonyms, e.g. "Salty taste" and "No salty taste". Prior to the test, the understanding of the CATA list was tested through a pilot study with five children of the age group.

In total, 109 children participated in the test. The test questions were presented on a paper questionnaire (displayed in supplementary material, Figure S.2). The children executed the test in subgroups of five, with three experimenters available for assistance in, for example, tasting the right sample, reading challenging words or remembering to rinse between samples. In the first page of the questionnaire, the children were asked to indicate age and gender. The eight samples were presented in a sequential monadic balanced presentation order, coded with single capital letters A-H. Each sample was first evaluated for overall liking on a 1 to 7-point scale with three emojis (unhappy, neutral, happy) as anchors, followed by the Check-all-that-apply (CATA) evaluation on the same page. The test instruction did not specify how many attributes should be ticked. Attributes were randomized across children to prevent position biases but kept constant across sample evaluation as per the recommendation by Meyners and Castura (2016). Between the samples, the children were instructed to rinse their mouth with water. At the end of the test, an ideal (imaginary) sample was evaluated for liking and CATA.

2.2.2. Smoothie test

The Smoothie test tried to overcome some of the challenges encountered in the Bread test. The main focus was to improve the autonomy of the children during the test, particularly with regards to attribute reading and understanding. To ensure a good understanding of the CATA attribute list, children of the age group developed attributes with the repertory grid method. Twelve children established 59 attributes. The experimenters reduced their attributes based on the frequency of elicitation and synonym reduction to the following 15: Light colour, Dark colour, Bubbles, Thin, Thick, Slimy, Very sour, Banana, Lemon, Strawberry, Raspberry, Blueberry, Strong smell, Yummy, Yuck. The list included two hedonic attributes "Yummy" and "Yuck" as well as an odour attribute "Strong smell".

To address reading challenges previously observed with the 6- and 7-year-olds (2nd graders), the children read the attributes with the teachers in class and with parents when they signed the consent form before the test. The questionnaire was electronic with little text to minimize the reading effort. A monkey story was introduced in the test in order to increase engagement: the participants were asked to help the experimenters find out what type of smoothies a monkey that had broken into a smoothie factory had produced (displayed in supplementary material, Figure S.8).

In total, 93 children participated in the test. The test was performed on tablets. At the start of the test session, the experimenters explained

Table 1
Sample design with DoE factors. Low factor level = 0, high factor level = 1.

	DoE Bread			DoE Smoothie		
Sample name	Salt 0 = 0.4% 1 = 1.2%	Coarseness 0 = fine flour 1 = coarse flour	Darkness 0 = - 1 = Caramel colouring	Thickness 0 = - 1 = Xanthan gum	Colour intensity 0 = - 1 = Beetroot powder	Acidity 0 = - 1 = Lemon juice
*1, 1_1**	0	0	0	0	0	0
2	1	0	0	1	0	0
3	0	1	0	0	1	0
4	1	1	0	1	1	0
5	0	0	1	0	0	1
6	1	0	1	1	0	1
7	0	1	1	0	1	1
8	1	1	1	1	1	1

* Note: Sample 1_1 was only used in the Smoothie test as "Warm-up" sample.

and demonstrated the test. Then the children conducted the test independently. The children executed the test in subgroups of ten, with three experimenters available for assistance. The first page of the questionnaire asked school grade and gender, followed by the sample-related questions. The original smoothie with the low factor levels (no colour, no thickener, no lemon juice added) was first evaluated as "warm-up" sample (sample 1_1, Table 1). The same sample (named "sample 1") was then again presented in sequential monadic balanced presentation order with the other test samples, coded with distinct symbols (e.g. a lightning). Each sample was first evaluated for overall liking on a 1 to 7-point scale with seven emojis (from unhappy to happy) followed by the CATA evaluation on the next page. As in the Bread case study, the attributes were randomized across children, but kept constant across samples. However, the electronic questionnaire required the ticking of at least one CATA attribute to continue to the next sample preventing missing answers. Between the samples, the children were instructed to rinse their mouth with water. No ideal sample was evaluated in this case.

2.3. Quantitative descriptive analysis with trained panel (QDA)

A Generic descriptive analysis (based on QDA as described by Lawless and Heymann (2010)) was performed for each set of samples by the trained profile panel of Nofima. Nofima's panel is highly trained and very stable. The assessors are solely hired as tasters, and some of them have more than 30 years' experience working with descriptive analysis. Panel performance is checked for every project, based on three qualities: discrimination, repeatability and agreement. The descriptive terminology of the products was created in a pre-trial session using samples that stretched the sensory space. After a 1-h pre-trial session, the descriptors and definitions were agreed upon by the assessors; all assessors were able to discriminate among samples, exhibited repeatability, and reached an agreement with other members of the group. For the bread samples the following 18 attributes were defined: Acidic odour, Grain odour, Cloying odour, Colour hue, Colour strength, Whiteness, Hardness, Juiciness, Coarseness, Chewing resistance, Sticky, Doughy, Acidic taste, Sweet taste, Salty taste, Bitter taste, Corn taste, Cloying taste. For the smoothie samples, the following 18 attributes were defined: Intensity smell, Acidity smell, Fruity Berry smell, Artificial smell, Colour intensity, Whiteness, Taste intensity, Acidity, Sweetness, Sourness, Bitterness, Metallic, Fruit Berry, Artificial, Fullness, Viscosity, Astringency, Pungency. After a pre-testing, nine panellists rated each sample in duplicate on a 10-cm scale.

2.4. Statistical analysis

2.4.1. Usage of CATA list, ticking style indicators

To find out how the children used the CATA attributes, we described their ticking behaviour with three ticking style indicators: The total number of ticks for the eight randomized samples (called "number"), the standard deviation in the number of ticks per sample (called "std") and the number of different CATA attributes (called "attributes") used per child. "Attributes" was regarded as relevant to compare the usage of a researcher-developed CATA list in the Bread test and a child-generated CATA-list in the Smoothie test.

A PCA of the children as rows and the three standardized ticking style variables as columns was performed. Based on the interpretation of the first two components, three equally sized ticking style groups were built. The ticking style groups were compared regarding age in the Bread dataset and school grade in the Smoothie dataset with a χ^2-test.

2.4.2. Analysis of CATA data

The Cochran's Q test was used to test for differences between samples regarding the number of ticks of a CATA attribute. The ticking or no ticking of an attribute was defined as the binary response variable, sample as a fixed factor and child as block factor.

A correspondence analysis (CA) of the contingency table of the CATA attributes was performed. The not significant attributes were included for better comparability of the ticking style groups where the significance was not conclusive due to their smaller sample size. For better interpretation and comparability of the score plots, the levels of the three design of experiment (DoE) factors were projected as supplementary qualitative variables into the plot. The "Ideal" sample in the Bread study and the "Warm-up" sample "1_1" in the Smoothie study were projected as supplementary rows into the score plot. The projection of the supplementary variables was done with the FactoMineR R package according to Lê, Josse, and Husson (2008). The supplementary variables did not influence the configuration.

To compare the perceptual space of the three ticking style groups, a multiple factor analysis (MFA) was performed using the contingency tables of each ticking style group defined as a frequency table. Again, the DoE factor levels were projected into the plot as supplementary qualitative variables. For better readability, the plot only displayed the DoE factor levels of the overall configuration as well as the partial coordinates of the ticking style groups.

2.4.3. Analysis of QDA data

The significance of the QDA attributes regarding sample discrimination was determined with a Mixed effect ANOVA. The rating on a scale (1 to 10) of the attributes was defined as the continuous response variable, samples as a fixed factor and trained assessors as well as the assessor x sample interaction were considered as random factors.

A principal component analysis (PCA) was performed with the significant unstandardized QDA attributes. The levels of the three design of experiment (DoE) factors were projected as supplementary qualitative variables into the score plots.

2.4.4. Liking

The influence of the DoE sample differences on the liking rating were analysed with a Mixed ANOVA, with the DoE factors and second order interactions as fixed and child as well as second order interaction of child x DoE factors as random.

The correlation of the average liking of the samples with the first three components of the perceptual space of the children (CA and MFA) and trained profile panel (PCA) was calculated and displayed in correlation circles.

2.4.5. Similarity index

The similarity between the perceptual space of the children and the trained profile panel was measured with the similarity index (SMI) introduced by Indahl, Næs, and Liland (2018); the first component, the first two components, as well as the first three components of the score plots, were compared. The SMI was chosen over the more frequently used RV coefficient because it weighs the three components more equally while the RV coefficient weighs the first component most. It must be noted that the SMI, as well as the RV coefficient, overestimate the similarity of the present matrices because the row versus column ratio was relatively small in the score plot matrices.

2.4.6. Investigation in underlying reasons for ticking style

In order to further analyse ticking behaviour, we analysed the influence of three different variables on the ticking number per sample. It was of interest if the number was linked to certain samples, the hedonic response to them or tasting order. The liking ratings were transformed to ranks within child to avoid scale effects, the sample with the lowest rating was assigned the lowest rank, 1 and the sample with the highest rating was assigned the highest rank, 8. For ties the average of the ranks was assigned to the corresponding samples. A mixed regression model then analysed sample, ranked liking and tasting position as fixed effect and child as random effect.

2.4.7. Data and software

Both datasets, Bread and Smoothie, are available as supplementary data. For the data analysis the software R, version 3.5.1 was used (code available from corresponding author on request). The package FactoMineR for CA, MFA and PCA, the lmerTest and mixlm as packages for Mixed effect models, the RVAideMemoire package for Cochran's Q test and the MatrixCorrelation package for SMI calculation was used.

3. Results

3.1. Usage of the CATA list

The Bread questionnaire was paper-based and assisted by researchers. Several children's evaluations contained missing answers. These incomplete datasets, 26 in total, were excluded from this data analysis. The remaining 83 children used the CATA list in different ways. Fig. 1 presents a summary of ticking style indicators for the Bread and Smoothie studies. The distribution of the ticking style indicators is displayed as a histogram, the lower plots show the correlation between the variables as scatter plot, and the upper squares display their Pearson correlation values. In the Bread test, one child only ticked twice during the whole test while the most active child ticked 33 times (see ticking style indicator: "number" in Fig. 1). Some children used one of the ten available attributes across all samples, while others used up to eight different attributes across all samples (ticking style indicator: "attributes" in Fig. 1). None of the children used all ten available attributes. Some children displayed a high standard deviation in the number of ticks per sample (ticking style indicator: "std" in Fig. 1) varying in the ticking number per sample. In contrast, others ticked a similar number of attributes for all samples.

The electronic questionnaire of the Smoothie test required the evaluation of all samples, ticking at least one CATA attribute per sample. Therefore, no answers were missing, and all 93 answers could be considered for the analysis. The minimal number of ticks was eight, corresponding to one tick per sample. In this test, some children used all 15 available CATA attributes across all samples ("attribute") which indicates that the child-developed attributes were well applicable. The analysis of the ticking style revealed one outlier displaying an extremely high standard deviation. The inspection of this boys ticking data showed that he had ticked almost all attributes for half of the samples while for the other half, he had only made one tick per sample which was required by the electronic questionnaire in order to continue. It can be assumed that he did not use the CATA list to describe his perception of the samples and his data were excluded from further data analysis.

Inherently, the three ticking style variables "attribute", "std" and "number" were linked to a certain extent. The correlation between the ticking style indicators "number" and "attribute" was high in both studies (0.73 in Bread, 0.80 in Smoothie). The third ticking style variable "std" displayed a low correlation in the Bread study (0.08 with "number", 0.29 with "attributes") and an intermediate correlation in the Smoothie study (0.65 with "number", 0.56 with "attributes"). Next, it was of interest how the different ticking styles influenced the perceptual space generated by the children. A PCA of the three ticking style indicators, "number", "attributes" and "std", indicated a tendency for a split in three groups of children in both datasets (Fig. 2). There was one group low in all ticking style indicators, the "few tickers". This group was defined as the lower third of PC1. The remaining children were split into almost equally sized groups (due to the uneven number) based on PC2. Children that ticked frequently displaying a high standard deviation were defined as the "variable tickers". Children that ticked frequently displaying a low standard deviation were defined as the "steady tickers".

The "few tickers" ratio decreased with age, as displayed in Fig. 3, indicating that this ticking style might be related to cognitive limitations, e.g. difficulties to read and understand the CATA attributes. However, no significant difference between the age groups / school grades in either of the datasets was found with the χ^2-test, (p-value: 0.428 in Bread, 0.476 in Smoothie).

3.2. Check-all-that-apply and liking of children

Table 2 shows the number of ticks in total and the significance of each CATA attribute for the total panel as well as for the ticking style groups. It was of interest if the children discriminated the samples with CATA attributes representing the three DoE differences between the samples. Table 3 shows the influence of the DoE differences on liking. It was of special interest if the children could describe their drivers of liking with CATA attributes.

In the Bread case study (Table 2), the two attributes "Light colour" and "Dark colour" representing the DoE factor *Darkness* were significant for all ticking style groups. *Coarseness* was represented by the three antonym pairs "Grainy", "Not grainy", "Coarse", "Not coarse" as well as "Easy to chew", "Hard to chew". One or both antonyms representing grainy and coarse were significant in each ticking style group. Only the "variable tickers" differentiated the samples regarding the chewing aspect "Easy to chew". The overall ticking number suggests that all samples were perceived as "Easy to chew" which was ticked 405 times while "Hard to chew" was only ticked 95 times. So, the "variable tickers" were the only group that described the relative difference between the samples. For the DoE factor *Salt* one of the two antonyms, "Salty taste", was significant. Conclusive analyses of the ticking style groups regarding discrimination are not possible due to the small group sizes of the ticking style groups. However, p-values indicate a tendency that the "variable tickers" discriminated the samples with the attribute "Salty taste" more (p-value = 0.06) than the "few tickers" (p-value = 0.56) and the "steady tickers" (p-value = 0.18).

The liking evaluation based on the pre-defined DoE factors (Table 3) revealed different preference patterns for the ticking style groups. For the overall panel as well as for the "variable tickers" and "steady tickers", *Salt* and the interaction *Darkness* × *Coarsness* determined the

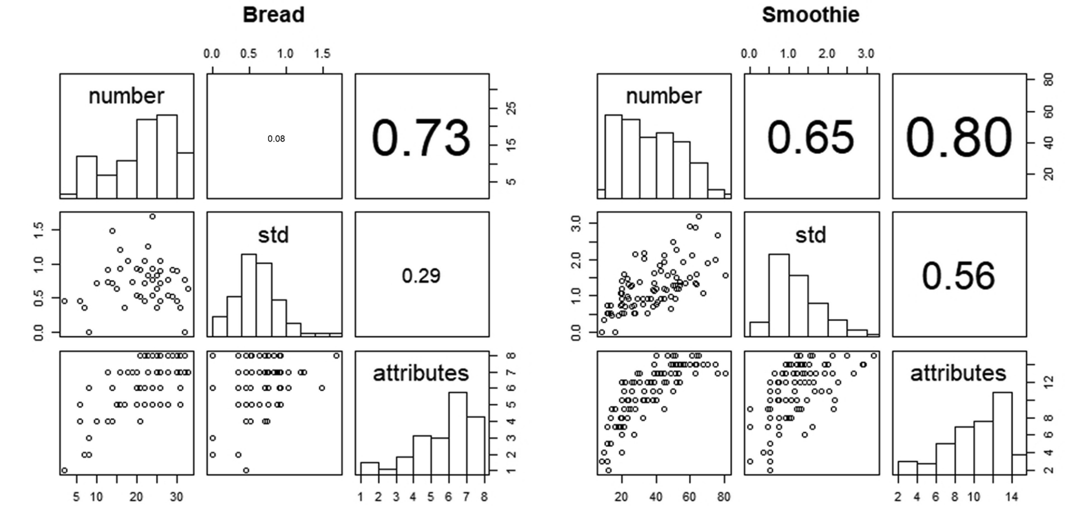

Fig. 1. Ticking style indicators (number, std and attributes) for the Bread (left) and Smoothie (right) study. Histogram of distribution in the diagonal, visual correlation in the lower panel and Pearson correlation in the upper panel.

liking. However, for the "few tickers" only the texture aspect, *Coarseness* was a driver of disliking.

The Smoothie case study (Table 2) included some attributes that did not represent the DoE differences directly. Some of them were significant in the discrimination between samples, e.g. the two hedonic attributes ("Yummy" and "Yuck") and fruit flavour attributes not directly referring to the difference in *Acidity* ("Banana" "Strawberry", "Blueberry"). The "steady tickers" discriminated the samples with a high number of the CATA attributes covering all three DoE factors. The "variable tickers" discriminated less but covered the three DoE factors while the "few tickers" discriminated less but also did not display any significant texture attributes that could represent the DoE difference in *Thickness*.

For all ticking style groups the DoE factor *Acidity* determined liking (Table 3). The lower acidity level was preferred.

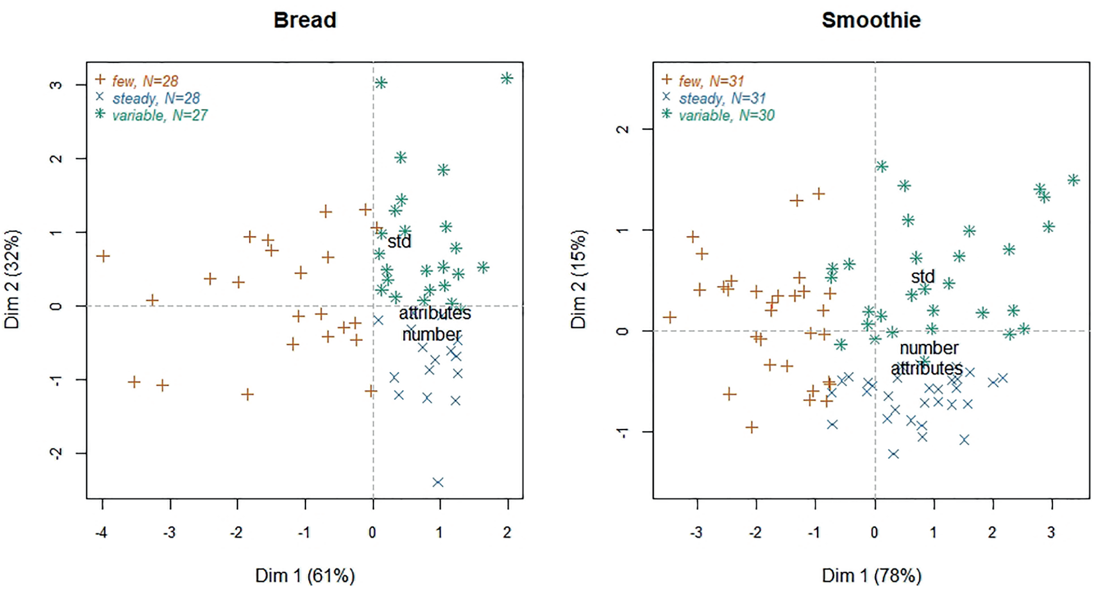

Fig. 2. PCA Biplot of ticking style indicators, individuals grouped according to ticking style. Three ticking style groups were built based on the first two PCA components of the standardized ticking style indicators. Individuals are coloured according to the ticking style group.

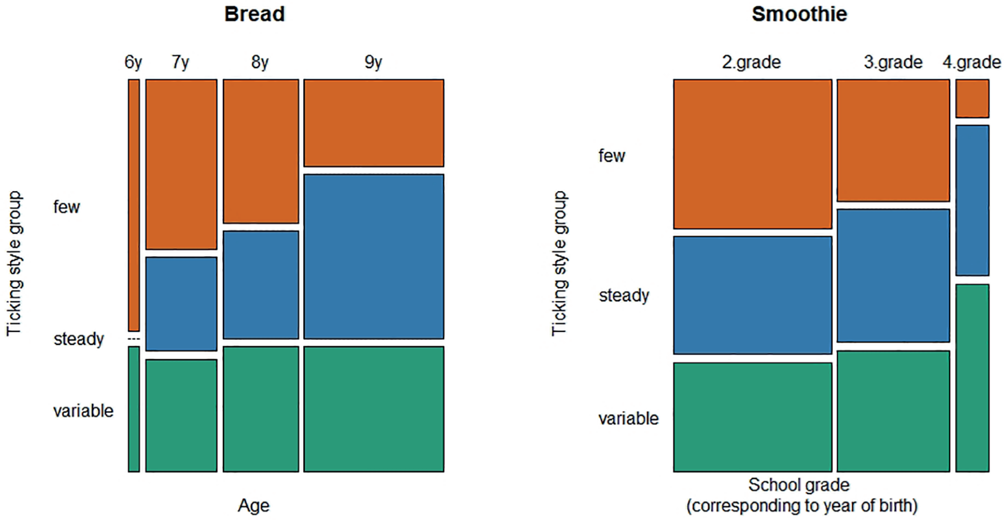

Fig. 3. Mosaic plot displaying the ticking style group sizes per age group in Bread / school grade (2.grade: 6–7 years old, 3.grad: 7–8 years old, 4. Grade: 8–9 years old) in Smoothie.

3.3. Comparison to trained panel

The analysis of the perceptual space allowed to check if the children discriminated the samples according to the underlying DoE factors and to evaluate the correlation of the components with the average liking. Further, it allowed the comparison with the trained profile panel. Fig. 4 (Bread) and Fig. 5 (Smoothie) show a CA of the CATA contingency table, a MFA comparing the contingency tables of the ticking style groups as well as a PCA of the QDA rating by the trained panel. The first three components of the score plots with the DoE factor levels projected for better interpretability are displayed as well as the correlation with the average liking. Loading plots of QDA and CATA as whole, as well as per ticking style group can be found in the supplementary material (Supplementary Figures S.3-S.7 for Bread and S.9-S.13 for Smoothie). Average values for liking and QDA are displayed in the supplementary material as well: Supplementary table S.1-S.4. Table 4 displays the similarity index (SMI) between the CA score plots of the children and the PCA score plot of the trained panel.

Table 2
Significance of CATA attributes for total child panel and ticking style groups.

Dataset	Related to DoE factor	CATA attributes	Number of ticks total	Cochran's Q Test (p-values): Total (N = 83/92)	Few tickers (N = 28/31)	Steady tickers (N = 28/31)	Variable tickers (N = 27/30)
Bread	*Darkness*	Light colour	290	**0.000**	**0.000**	**0.000**	**0.000**
		Dark colour	245	**0.000**	**0.000**	**0.000**	**0.000**
	Coarseness	Not grainy	172	**0.000**	**0.026**	**0.000**	**0.002**
		Grainy	273	**0.000**	**0.000**	**0.000**	**0.000**
		Easy to chew	405	0.057	0.822	0.489	**0.047**
		Hard to chew	95	0.179	0.280	0.688	0.069
		Not coarse	137	**0.000**	0.664	**0.000**	**0.012**
		Coarse	216	**0.000**	**0.022**	**0.000**	**0.001**
	Salt	No salty taste	255	0.094	0.525	0.368	0.875
		Salty taste	174	**0.012**	0.555	0.184	0.063
Smoothie	*Colour intensity*	Light colour	123	**0.000**	**0.001**	**0.024**	**0.030**
		Dark colour	323	**0.000**	**0.020**	**0.007**	0.278
	Thickness	Bubbles	250	0.064	0.165	**0.037**	0.594
		Thin	201	**0.005**	0.479	**0.008**	0.257
		Thick	245	**0.000**	0.259	**0.000**	**0.008**
		Slimy	167	**0.002**	0.865	**0.030**	0.053
	Acidity	Very sour	226	**0.000**	**0.001**	**0.000**	**0.009**
		Lemon	267	**0.000**	**0.002**	**0.000**	**0.048**
	Acidity (indirect)	Banana	237	**0.005**	0.165	0.151	**0.011**
		Strawberry	315	**0.000**	**0.002**	**0.001**	0.136
		Raspberry	308	0.155	0.559	0.772	0.152
		Blueberry	267	**0.005**	0.069	0.234	0.200
	Other (Odour)	Strong smell	149	0.203	0.780	0.192	0.728
	Other (Hedonics)	Yummy	262	**0.000**	0.435	**0.000**	**0.000**
		Yuck	91	**0.000**	**0.018**	**0.003**	**0.034**

Note: N = (N_{Bread} / $N_{Smoothie}$).

Table 3
Influence of DoE factors on 7-point-liking rating, p-values.

	DoE factor	p-values			
		Total (N = 83/92)	Few tickers (N = 28/31)	Steady tickers (N = 28/31)	Variable tickers (N = 27/30)
Bread	*Darkness*	0.283	0.274	0.878	0.159
	Coarseness	**0.012**	**0.042**	0.586	0.106
	Salt	**0.000**	0.251	**0.021**	**0.000**
	Darkness × *Coarseness*	**0.000**	0.322	**0.011**	**0.004**
	Darkness × *Salt*	0.483	0.138	0.298	0.218
	Coarseness × *Salt*	0.666	0.766	0.496	0.749
Smoothie	*Colour intensity*	0.255	0.198	0.174	0.568
	Thickness	0.306	0.054	0.846	0.897
	Acidity	**0.000**	**0.000**	**0.000**	**0.000**
	Colour intensity × *Thickness*	0.795	0.846	0.481	0.967
	Colour intensity × *Acidity*	0.465	0.332	0.901	0.708
	Thickness × *Acidity*	0.165	0.415	0.901	0.090

Note: $N = (N_{Bread} / N_{Smoothie})$.

In the Bread case study, the three DoE factors were each represented by one component of the perceptual space of the children as well as of the trained panel (Fig. 4). The colour difference *Darkness* was represented by the first component, *Coarseness* by the second component and *Salt* by the third. The perceptual difference in *Salt* was relatively small compared to the other two DoE factors, although it most strongly correlated with liking. The MFA plot where the ticking style groups are compared shows that the "variable tickers" described the most liking-relevant difference in *Salt* level in the third component most. The "few tickers" differed in their preference from the other groups. For this group, the DoE factor *Coarseness* was more correlated with their liking. The imaginary ideal sample (Ideal) was well aligned with the liking.

In the Smoothie case study (Fig. 5), *Acidity* was most strongly correlated with liking and also represented by the first component. All

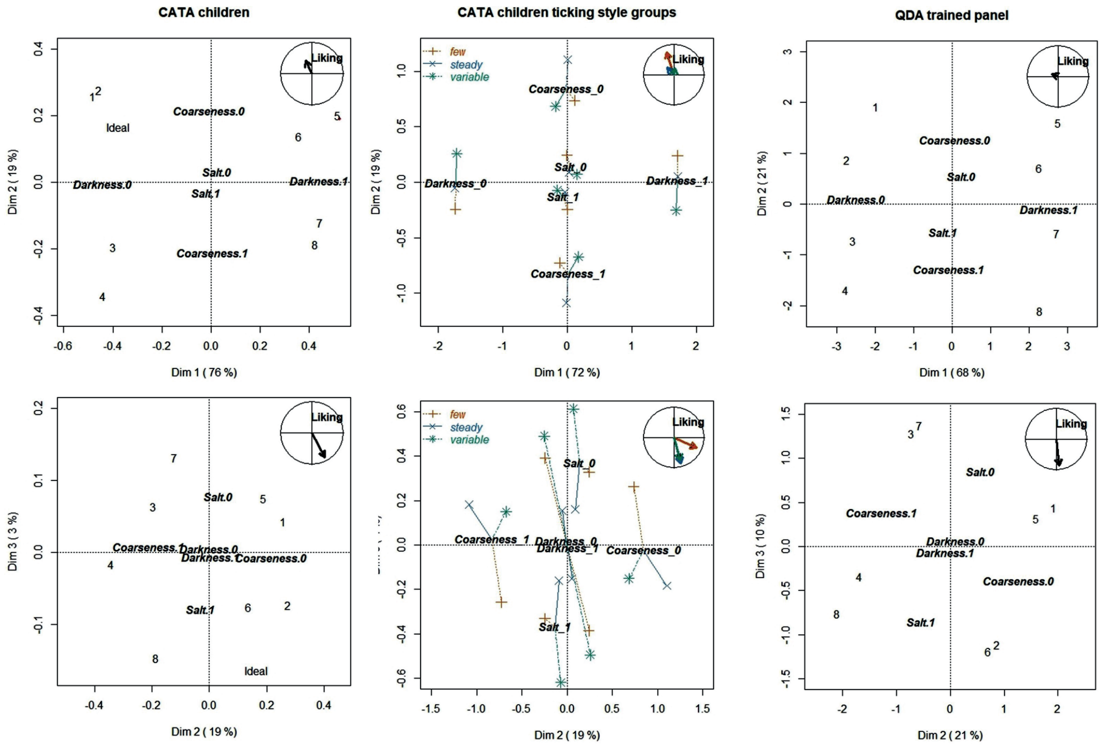

Fig. 4. Bread: Score plots: left: CA, middle: MFA, right: PCA each with liking in correlation circle. For better interpretation of samples the DoE factor levels are projected as supplementary variables. The centre of text corresponds to the exact location. In the MFA the partial coordinates of the DoE factor levels of each ticking style group are connected to the overall MFA configuration. Top row: Component 1 & 2, bottom row: Component 2 & 3.

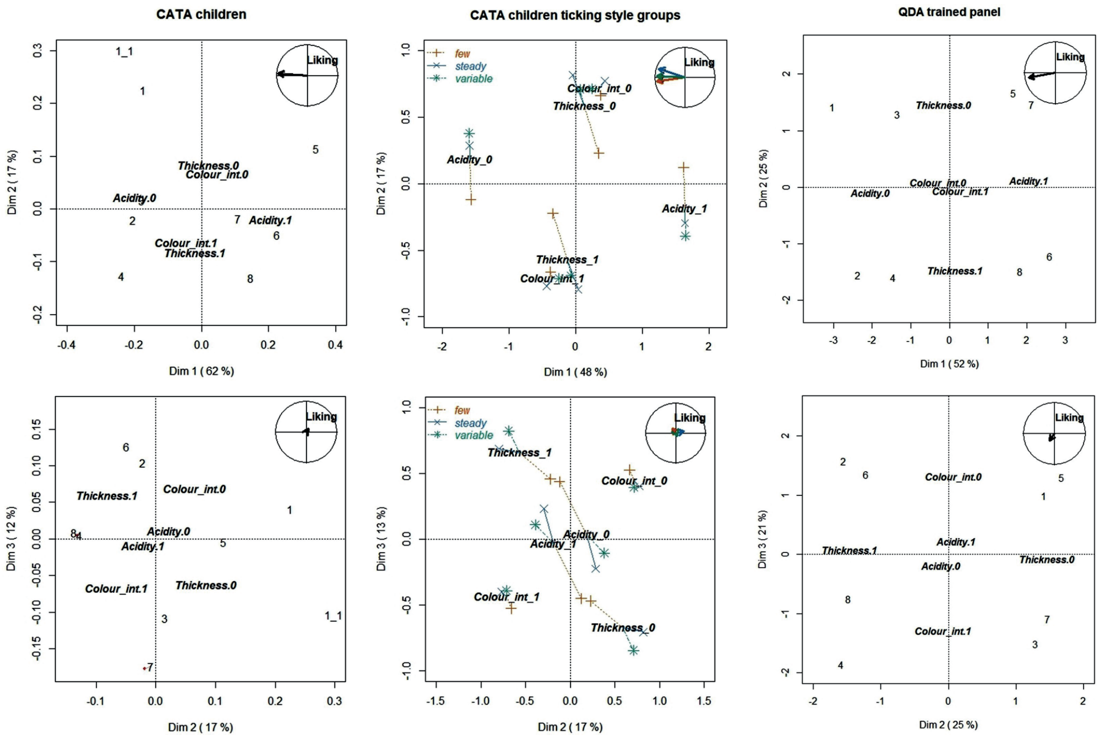

Fig. 5. Smoothie: Score plots: left: CA, middle: MFA, right: PCA each with liking in correlation circle. For better interpretation of samples the DoE factor levels are projected as supplementary variables. The centre of text corresponds to the exact location. In the MFA the partial coordinates of the DoE factor levels of each ticking style group are connected to the overall MFA configuration. Top row: Component 1 & 2, bottom row: Component 2 & 3.

ticking style groups could discriminate the samples regarding *Acidity*. In the second component, the thinner and lighter samples and thicker and darker samples were more often described by the same attributes, so that the DoE factors *Thickness* and *Colour* overlapped. Considering the third component, the factors *Thickness* and *Colour* were separated, however. The trained panel showed a similar perceptual space, however the association of DoE factors *Thickness* and *Colour* in component 2 was not apparent. The warm-up sample 1_1, which was composed of the low factor levels and identical to sample 1, was well placed in the first two components, *Acidity_0* and *Thickness_0*, but not in the third component, *Colour_int_0*. The colour attributes "Light colour" and "Dark colour" only became applicable over the test once darker samples had been presented. In contrast, the attributes describing *Acidity* and *Thickness* were applicable in a more absolute way, less relative to the sample space.

In both case studies, the similarity index (SMI) between the first three score plot components of the trained profile panel and the complete child panel was high, 0.94 in the Bread dataset and 0.93 in the Smoothie dataset (Table 4). The "few tickers" were the least aligned with the trained panel over the three components in both studies while the "variable tickers" as well as the "steady tickers" were well aligned with the trained panel.

3.4. Investigation in variable ticking behaviour

In the presented datasets, the "variable tickers" produced a good sample discrimination and detection of pre-defined sample differences. We first hypothesized that the variable ticking behaviour was sample induced, e.g. by the intensity of the DoE factor level or by the children's hedonic responses to them.

Table 4
Similarity of perceptual space: children and trained profile panel SMI Index comparing dimension 1, dimensions 1 to 2 and dimensions 1 to 3 of the score plots.

Dataset	Component(s)	SMI: similarity between CATA and QDA			
		Total (N = 83/92)	Few tickers (N = 28/31)	Steady tickers (N = 28/31)	Variable tickers (N = 27/30)
Bread	1	0.98	0.97	0.98	0.96
	1 to 2	0.92	0.92	0.88	0.93
	1 to 3	0.94	0.73	0.90	0.92
Smoothie	1	0.81	0.66	0.87	0.78
	1 to 2	0.77	0.39	0.74	0.77
	1 to 3	0.93	0.44	0.94	0.89

Table 5
Potential influences on ticking number of “variable tickers”: sample, ranked liking and tasting position.

Dataset	Variables	P-value
Bread, variable ticking style group, N = 27	Sample	0.422
	Liking (ranked)	0.795
	Tasting position	**0.000**
Smoothie, variable ticking style group, N = 30	Sample	0.571
	Liking (ranked)	0.068
	Tasting position	**0.000**

However, the present data suggest that the tasting position of the sample played a more important role than the sample properties or the hedonic response (Table 5). The “variable tickers” increased their ticking number along the test. In the beginning, they ticked fewer, and in the end, they ticked more attributes in both datasets, as shown in Fig. 6. The good results of the “variable tickers” could indicate that learning took place over the test. The attributes became relevant and more applicable once the sample space was apparent. This hypothesis is supported by the difference in the placement of the warm-up sample 1_1 in the perceptual space of the two ticking style groups in the Smoothie study in Fig. 7. The warm-up sample 1_1 was placed close to the corresponding sample 1 in all three dimensions for the “steady tickers”. However, for the “variable tickers”, sample 1 was placed opposite of warm-up sample 1_1 in the third dimension which indicates that the “variable tickers” adjusted their ticking in a relative way. In the Bread study, all ticking groups showed a slight increase in the number of ticks which might be linked to antonym-based attribute structure which could promote a relative ticking style, while in the Smoothie dataset, this trend is only observable in the “variable tickers”.

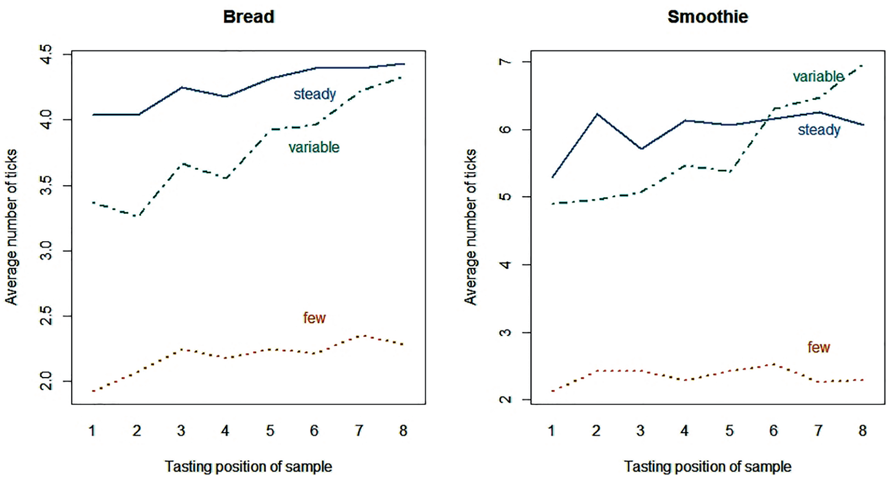

Fig. 6. Average number of ticks and tasting position of sample for ticking style groups.

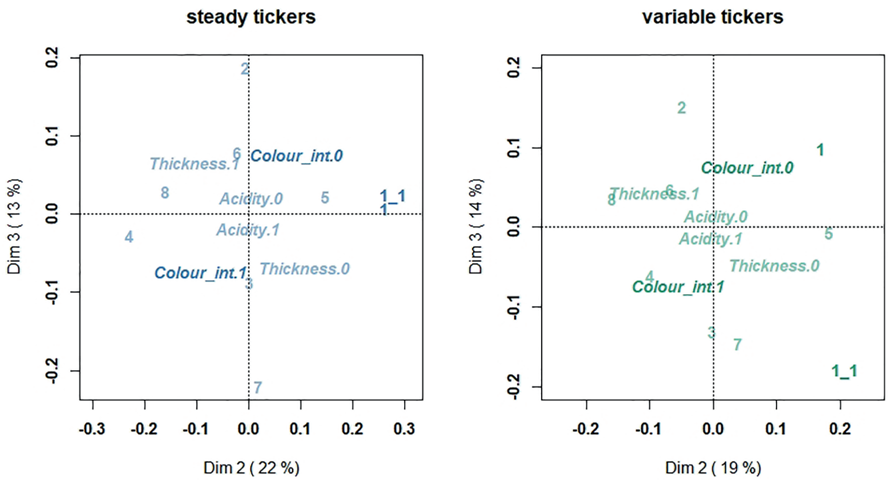

Fig. 7. Smoothie: CA score plots (Dim 2 and 3) for two CATA ticking style groups: “steady tickers” (left) and “variable tickers” (right). The warm-up sample 1_1 is projected as supplementary row, not influencing the sample configuration. For better interpretation of samples the DoE factor levels are projected as supplementary variables as well. The centre of text corresponds to the exact location.

4. Discussion

4.1. Assessment of CATA for sensory description with children and determination of their drivers of liking

As shown by Laureati, Cattaneo, Lavelli, Bergamaschi, Riso, and Pagliarini (2017) and Lima, Ares, and Deliza (2018), children were able to discriminate samples regarding pre-defined sample design differences. The two case studies analysed in the present paper also showed for the first time that the alignment with a trained profile panel was generally very high, for the consensus perceptual space. The high alignment to the trained panel indicates that the majority of the children's usage of the CATA list was guided by their sensory perception, which they could accurately point out with the CATA list. However, our results indicate that ticking style plays an important role regarding data validity which is discussed further in the next Section 4.2.

In both case studies, the design factor representing the sensory modality taste was the main driver of liking. In the Smoothie study *Acidity* was also the predominant factor of the perceptual space. In the Bread study, *Salt* was the least important factor in terms of product description, only apparent in the third component. As this factor was also only visible in the third dimension of the perceptual space of the trained panel, it can be assumed that it was the least salient DoE factor difference regarding perception.

4.2. Implications of ticking style

The analysis of the ticking style indicators revealed some participants that could not use the CATA list accurately to describe their perception. Ticking style indicators can, therefore, be valuable to find outliers, e.g. eliminating consumers from the data analysis with a low ticking "number" or low number of "attributes". The elimination of the "few tickers" from the data analysis might be especially relevant when the setup of an electronic questionnaire requires a minimal number of ticks, and when young children participate in the test. In the two case studies, the proportion of children in the few ticking group decreased by age in trend. Therefore, the few ticking behaviour is likely linked to cognitive limitations. In her review Anderson (1998) described how executive functions such as ability to resist distraction and verbal fluency, of which a certain degree is a pre-requirement for the successful performance of a CATA test, are only mature by the age of 12 and older and large individual differences occur.

Against the observation that the children tended to get bored over the test which could lead them to tick a smaller number of CATA attributes, a hypothesis, e.g. also mentioned by Jaeger et al. (2015) for adults, our analysis of ticking style indicators showed the opposite. While the "steady tickers" kept their ticking number constant over the test, the "variable tickers" increased their number of ticks over the test. This increase makes perfect sense for the relative nature of sensory evaluations, especially in the case of the CATA method where the response to a continuous stimulus has to be transformed into a binary answer. To describe a sample as "Salty" becomes more relevant once a less salty sample has been tasted. The occurrence or non-occurrence of this increased ticking behaviour points to different underlying test strategies: The "steady tickers" might use the CATA attributes in a more absolute sense. In contrast, the "variable tickers" might use them in a more relative sense considering the sample space that gradually unfolds to them during the test. Our data validation did not show a clear superiority of one strategy over the other.

More generally, this finding points to a phenomenon likely to underly many sensory consumer tests where samples are presented in a sequential monadic design. Consumers are generally instructed to rate a sample independently of previously tasted samples. However, many consumers are likely to switch to a strategy where they contrast previously tasted samples, adjusting the scale to the sample space of the test. Lawless and Heymann (2010) described this effect as contrast effect, attributing it to an axiom of perceptual psychology: "Humans are very poor absolute measuring instruments but are very good at comparing things". Similarity-based method, such as the projective mapping, explicitly instruct the assessors to use a relative test strategy. It is likely that the "variable tickers" would produce similar perceptual spaces with the CATA method and with a similarity-based method, while the "steady tickers" would produce different results.

4.3. Implications of the test protocol

Table 6 highlights the learnings from the two case studies for future CATA test setups with children.

In the first case study with Bread where researchers developed sample-relevant CATA attributes, some CATA attributes were not understood by all children. Our data analysis showed that the sample- and age-relevant CATA list developed by children in the Smoothie case study was more fully used than the list developed by researchers, both regarding the ticking style indicator "number" which might also be

Table 6
Challenges and recommendations for CATA tests with children.

Challenge	Recommendation	Comment
Understanding CATA attributes and relating them to samples	Vocabulary development with children of targeted age group based on samples in experiment	A repertory grid approach may be used to generate attributes
Reading effort dominates the task	Pre-familiarisation with the CATA list	For the youngest, reading in class and/or parents prior to the test is recommended
Time-consuming (reading)	Use as little text as necessary for instructions	Better to do a live instruction than explaining in text
Skipping pages	Usage of tablets	Pages cannot be skipped, and children handle tablets more easily than multi-page documents.
Forget to rinse mouth with water between samples	Reminder screen	Use an image (e.g. a glass of water) rather than a sentence
Losing interest after a few samples	Give a child-friendly purpose to the study	Inviting children to help adults is engaging. Use an age-appropriate cover story. It doesn't need to be credible as children under 10 y.o. enjoy fantasy.
Few attributes selected	Read the word, taste and tick if it applies	"click all words that apply" is too generic and they may not go through the list systematically
Confuse samples	Usage of distinct symbols or alphabetic letters	A,B,C,D,E,F,G,H 
Ideal product is misunderstood	Trigger children's imagination	
CATA list is applied in an absolute manner, not restricted to the sample space	Include a "warm-up" sample	The list will be used in a sample-space relative manner.

related to the higher number of available attributes, but also regarding the number of different attributes used throughout the test, "attributes". Moreover, no attribute explanations were necessary during the Smoothie data collection, while "Coarse" generated several questions in the Bread study. Regarding data validity, both the sample-relevant CATA list based on antonyms and the sample- and age-relevant CATA list were suitable. The sample-relevant CATA list produced a perceptual space that divided the samples based on one DoE factor in each component. In comparison, the less systematic sample- and age-relevant CATA list revealed an interaction between two sample design factors, *Colour* and *Thickness* which was not found in the perceptual space of the trained panel. Whether this can be attributed to the type of CATA list is not conclusive as the two case studies vary in too many aspects.

Special care should be taken setting up the questionnaire. The text throughout the test should be reduced to the minimum because reading takes more time for children. Instead of written instructions, a live demo of the test is useful and recommended. To increase children's motivation, the Smoothie study included a story explaining the purpose of their task. This favoured the engagement of children to fulfill the test despite its high level of repetitiveness.

Overall, the electronic questionnaire offered advantages over the paper questionnaire where children skipped pages, forgot to rinse their mouth with water between samples and needed a higher degree of assistance. An electronic questionnaire can include a page between samples as a reminder to rinse the mouth. Also, missing answers can be avoided. Another advantage is that with tablets the test looks and feels much more like a game. It has to be kept in mind, that the mandatory answers might trigger some wrong data as seen in the outlier discussed in Section 3.1.

A sequential monadic presentation in which samples are handed to the children one by one would be always the preferred choice, however, in some set ups (like school testing) this could not be possible, and a simplified marking of cups can help. Labelling samples with symbols instead of three-digit codes or letters makes the self-administered tasting easier and, in our experience, avoids the occurrence of sampling errors during tasting. Care should be taken in the choice of suitable symbols to avoid cross-modal influences of the symbols on taste perception. Deroy and Valentin (2011) for example, showed an association of certain shapes with certain tastes. Symbols differing in emotional valence might bias hedonic ratings of samples as well. On the other hand, ensuring that the child is tasting the right sample at any time was deemed more important than possible emotional valence bias.

The ideal sample in the Bread case study was well aligned with the liking. However, at data collection stage an explanation for the evaluation of an ideal sample is necessary as children are likely to think in a less abstract way than adolescents and adults, corresponding to the operational development stage described by Piaget (1964).

Our data analysis revealed that the CATA attributes became more relevant for one group, the "variable tickers", once the sample space was apparent. This sample space-relative ticking would speak for a training session or at least an anchoring "Warm-up" sample as done in the Smoothie case study in order to improve data quality.

4.4. Limitations and future research

This study sheds light on the topic of individual differences in approaching a consumer profiling method with children, i.e. CATA. Results highlighted groups of children performing the test in different ways. The segmentation for ticking style groups was done with the goal of building equally sized groups by a visual evaluation of the PCA plot in order to prevent very small groups. Due to the small sample size more detailed segmentation was not possible. More research with larger groups of children would be desired to confirm the findings of the ticking style groups. To the authors' knowledge, no study has been done studying the ticking style with CATA data of adults. It would be desirable to do so, preferably with a DoE underlying the test design, for a more controlled interpretation. Added to this, further studies are needed on different food categories, with smaller and larger differences among samples, to see to what extent these potential ticking groups may affect the outcome of the studies.

5. Conclusion

This paper unveils that individual differences underly how children 6–9 y.o. approach CATA tests, influencing the outcome, with potential implications for test design, validity check and interpretation of results. We propose three ticking style indicators to study this: number of ticks, standard deviation of number of ticks per sample, and number of different attributes used in the test. Our analysis revealed one group, the "few tickers", that used the CATA list scarcely and produced less informative data, potentially due to cognitive limitations. The other two groups produced valid data, closer to QDA by a trained panel, indicating that the test protocols were suitable for the majority of children.

Further analysis revealed that the latter two groups likely adopted different test strategies: The "variable tickers" increased their number of ticks over the test, implying a sample space-relative test strategy. In contrast, the "steady tickers" might have used the list in a more absolute way. Future research may investigate if children displaying a sample-space relative strategy in CATA are more capable of conducting other sample-space relative methods, such as projective mapping, than those relying on absolute strategies.

In our discussion we provided an overview of suitable child-friendly adaptations of the CATA test protocol for future studies. Future research should also aim at better understanding the effects of ticking style in other product categories and potential ticking groups in adult population.

CRediT authorship contribution statement

Martina Galler: Writing - original draft, Conceptualization, Investigation, Formal analysis, Visualization, Methodology. **Tormod Næs:** Conceptualization, Methodology, Supervision. **Valérie L. Almli:** Methodology. **Paula Varela:** Methodology, Conceptualization, Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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