Aarhus University

Step-by-step changes of children’s preferences towards healthier foods

PhD thesis by
Heidi Kildegaard
August 2011

Department of Food Science
Research Centre Aarslev
Science and Technology
Aarhus University
Kirstinebjergvej 10
5792 Aarslev
Denmark
Main supervisor
Head of research unit, senior scientist Anette K. Thybo,
Institute of Food Science, Aarhus University.

Co-supervisors
Associate professor Merete Edelenbos,
Institute of Food Science, Aarhus University.

Associate professor Per Møller,
Department of Food Science, University of Copenhagen.

Opponents
Associate professor Ulla Kidmose (chairman),
Institute of Food Science, Aarhus University.

Associate professor Michael Born Frøst
Department of Food Science, University of Copenhagen.

Dr. Sylvie Issanchou,
Institut National de la Recherche Agronomique (INRA), France.
PREFACE

This thesis represents work to fulfill requirements for a PhD at the Department of Food Science, Science and Technology, Aarhus University. The work was a part of a three-year research project funded by the Strategic Research Council for Food and Health. The title of the project was: *Step-by-step changes of children’s preferences towards healthier foods*. Partners in the project were: Mapp – Center for Research on Customer Relations in the Food Sector, Aarhus University, Department of Food Science, University of Copenhagen, and Department of Food Science, Aarhus University. In addition, several Danish food industry companies participate in the project group.

First, I would like to thank my academic advisors supervisor senior scientist Anette K. Thybo, Associated Professor Per Møller and Associated Professor Merete Edelenbos for valuable discussions in relation to this project. A very special thank go to my main supervisor Anette K. Thybo who was always positive and supporting. I have learned so much from her clear guidance and our discussions.

I also wish to express my gratitude to: Leslie Jørgensen, Rynkeby A/S, Søren Navne, Dairy Fruits A/S, Merete Myrup Christensen, Arla Foods amba and Mette Bendix Nielsen, Easy Foods A/S for their help in the development of new food products and Gorm Gabrielsen for helping with some data analysis.

Sidsel Jensen is greatly acknowledged for a thorough review and for her advices and very constructive feedback. Thank you for taking the time for it!
Also a special thank to all of you who helped me during the final writing process. Especially, I would like to thank all my colleagues at Department of Food Science, Årslev. You have all contributed to a positive, social and inspiring working environment and I have really enjoyed my time as PhD candidate.

Finally, I am deeply grateful for the support and patience that I received from my family and friends. In particular, my dear husband Carsten and our two children Mikkel Marius and Smilla Josefine have been absolutely essential for keeping up my energy and enthusiasm to finish this project. I am deeply grateful for this ♥.

August, 2011, Heidi Kildegaard
ABSTRACT

In recent years, obesity in children has been a growing health problem in the industrial part of the world (WHO) which is associated to children’s food choice and intake (Epstein, Salvy, Carr, Dearing, & Bickel, 2010). Children’s food choice and intake are highly influenced by sensory preferences. The overall aims in this PhD project were 1) to investigate how children’s food preferences for healthier foods can be changed by altering children’s preferences step-by-step, and 2) to investigate how food products can be changed step-by-step in a more healthy direction without loss in children’s preferences. These aims were fulfilled by studying the effect of strategies like mere exposure on perception of food products and by studying how various food products can be changed by understanding the influence of composition and product complexity on preferences. Thus, the overall focus during this PhD project has been on modelling of children’s food preferences and foods, simultaneously. In addition, the project included a picture-based conjoint layout to assess visual preferences, as visual preferences are hypothesized to predict food choice.

Paper 1-3 describe a new way of assessing children’s visual preferences by using a picture-based conjoint layout. In these studies pictures of products were presented on a computer screen in a conjoint manner. In Paper 1 and 2 an actual choice test of tangible products was further carried out and Paper 2 also included investigations of the influence of selected ‘segmentations factors’ and background characteristics on children’s visual preferences. The results showed that the picture-based method provided reproducible and valid information about children’s visual preferences as a high correlation between the picture-based conjoint layout and actual food choice was found. Factors such as colour, visible fruit pieces and novelty, various ‘segmentation factors’ and background characteristics significantly influenced children’s visual preferences.
Paper 4 and 5 describes the effect of step-by-step changing foods on children’s taste preferences, liking, wanting, and perception of sourness. In Paper 4, children evaluated beverages (apple juice and fruit drink) in designs with four different dry matter concentrations. The results showed that children on average preferred less sour beverages compared to the more sour ones, but a segment of children with high liking and wanting for the most sour apple juice was found. Additionally, it was found that children had an upper limit in preference for dry matter concentration (sweetness). In Paper 5, children evaluated fermented milk products (FMP) (named AMP in Paper 5) varying step-by-step in fat and fruit content. Results showed that liking and wanting were highest for FMPs with a high content of fruit. Fat content did not influence liking of FMPs with high fruit content whereas high-fat FMPs were most liked at low content of fruit. Based on collected background characteristics it was possible to segment children differing in ratings of liking and wanting in both studies. In Paper 6, the development in liking of FMPs with a step-by-step increase in designed complexity during mere exposure was examined. The results showed that only exposure to a FMP with a high level of designed complexity increased liking. Besides, addition of natural flavours masked the addition of fibres and fruit in FMPs.

In conclusion, this work showed that food appearance and children’s visual preferences are highly important to children’s food choice and that visual methods are able to predict food choice. Segments of children within the same age range have very different preferences; both visual- and taste preferences, indicating that strategies must be targeted specific segments to succeed in changing preferences in a more healthy direction. The results demonstrated that it is possible to change children’s preferences in a healthier direction by modelling the children’s food preferences by using mere exposure strategies and e.g., by modelling the food products by using masking strategies or by changing food complexity.
RESUME

Overvægt blandt børn er i de seneste år blevet et stigende sundhedsproblem i den industrialiserede del af verden (WHO), hvilket i høj grad kan associeres med børns valg og indtag af fødevarer (Epstein, Salvy, Carr, Dearing, and Bickel, 2010). Børns valg og indtag af fødevarer er i høj grad påvirket af de sensoriske præferencer. De overordnede formål i dette ph.d. projekt var 1) at undersøge, hvordan børns præferencer for sundere fødevarer kan ændres ved stepvist at ændre børns præferencer og 2) at undersøge, hvordan fødevarer kan ændres stepvist i en sundere retning uden tab af børns præferencer. Målene blev nået ved at undersøge effekten af strategier som for eksempel gentagen eksponering på opfattelsen af fødevarer samt ved at undersøge, hvilken betydning sammensætning og kompleksitet i produktet har på præferencen for produktet. Hovedfokus i ph.d. projektet var således på modellering af børns præferencer og fødevarer sideløbende.

Desuden inkluderede projektet en conjoint-analyse baseret på billeder til bestemmelse af børns visuelle præferencer, idet hypotesen er, at visuel præference kan prædiktere fødevarevalg.

Artikel 4-5 beskriver effekten af stepvist ændrede fødevarer på børns smagspræferencer, liking, wanting samt opfattelse af surhed. I artikel 4 evaluerede børn drikkevarer (æble juice og saft) designet med fire forskellige tørstof koncentrationer. Resultaterne viste generelt, at børn havde højst præference for de mindst sure drikkevarer sammenlignet med de mere sure varianter, men at der eksisterer et segment af børn med høj liking and wanting for den mest sure æblejuice. Desuden havde børn en øvre grænse i præference i forhold til tørstof koncentration (sødhed). I artikel 5 evaluerede børnene yoghurt med stepvise ændring i fedt- og frugtindhold. Resultaterne viste, at liking and wanting var højest for yoghurt med et højt indhold af frugt. For yoghurt med højt frugtindhold påvirkede fedtindhold ikke liking, mens liking for yoghurt med lavt frugt indhold var højst ved højt fedtindhold. På baggrund af de indsamlede baggrunde karakteristika var det muligt at segmentere børn med forskellig ratings af liking og wanting i begge studier.


Konklusionen på dette projekt er, at fødevarers udseende og børns visuelle præferencer er meget vigtig for børns fødevarevalg, samt at visuelle metoder kan prædiktere fødevarevalg. Segmenter af børn indenfor samme alderstrin har meget forskellige præferencer; både visuelle og smagspræferencer, hvilket betyder, at strategier skal målrettes specifikke segmenter for at lykkes med ændre børns præferencer i en sundere retning. Resultaterne viser, at det er muligt at ændre børns præferencer i en sundere retning ved at modellere børnenes fødevarer præferencer med strategier som gentagen eksponering, og ved at modellere produkterne med f.eks. maskerings strategier og ændringer i produkt kompleksitet.
LIST OF PUBLICATIONS

Measuring Children’s Food Preferences: Using Pictures in a Computerized Conjoint Analysis.
Journal of Sensory Studies, SUBMITTED.

Paper II Heidi Kildegaard, Annemarie Olsen, Gorm Gabrielsen, Per Møller, and Anette K. Thybo.
A method to measure the effect of food appearance factors on children’s visual preferences.

Adolescents and adults preference for pictures of fruit and vegetables mixes varying in complexity.
Food Quality and Preference, SUBMITTED.

Paper IV Heidi Kildegaard, Erik Tønning, and Anette K. Thybo.
Preference, Liking and Wanting for Beverages in Children Aged 9-14 Years: Role of Sourness perception, Chemical composition and Background Variables.

Paper V Heidi Kildegaard, Mette Marie Løkke, and Anette K. Thybo.
Effect of Increased Fruit and Fat content in an Acidified Milk product on preference, Liking and Wanting in Children.

Effects of Repeated Exposure to Fermented Milk Products with a Stepwise Increase in Designed Complexity on Children’s Liking.
Food Quality and Preference, SUBMITTED.
LIST OF ABBREVIATIONS

ANOVA: Analysis of variance
AMP: Acidified milk product
BMI: Body Mass Index
FFQ: Food frequency questionnaire
FMP: Fermented milk product
HF: High fat
kJ: Kilo Joule
LF: Low fat
PLS: Partial least square
L-PLS: L-Partial least square
MS: Metabolic syndrome
PCA: Principal component analysis
PLSR: Partial least square regression
PROP: 6-n-propylthiouracil
PTC: Phentylthiocarbamid
TABLE OF CONTENT

PREFACE…………………………… I
ABSTRACT…………………………... III
RESUMÉ……………………………… V
LIST OF PUBLICATIONS……………. XII
LIST OF ABBREVIATIONS……..XIII

INTRODUCTION ............................................................................................................................... 3
1 PREFERENCE, LIKING AND WANTING .................................................................................... 9
  1.1 Definition of terms ..................................................................................................................... 9
  1.2 Dissociation of liking and wanting........................................................................................... 10
  1.3 Factors influencing children’s food preferences ...................................................................... 13
    1.3.1 Visual preferences ............................................................................................................. 15
    1.3.2 Taste preferences ........................................................................................................... 16
  1.4 Gender, age and ethnical differences in food preferences........................................................ 19
2 SENSORY EVALUATION WITH CHILDREN ........................................................................... 24
  2.1 Sensory development in children ............................................................................................. 25
  2.2 Cognitive development stage ................................................................................................... 26
  2.3 Methodology for sensory evaluation with children .................................................................. 29
    2.3.1 Rating of liking .................................................................................................................. 29
    2.3.2 Ranking of taste preference ............................................................................................... 33
    2.3.3 Ranking of visual preferences ............................................................................................ 35
  2.4 Factors influencing sensory evaluation with children .............................................................. 38
    2.4.1 Peer influences .................................................................................................................. 38
    2.4.2 Time of day ........................................................................................................................ 39
3 CHANGING CHILDREN’S FOOD PREFERENCES ................................................................. 41
  3.1 Innate preferences ..................................................................................................................... 41
  3.2 Learned preferences ................................................................................................................. 42
    3.2.1 Effect of hunger .................................................................................................................. 43
    3.2.2 Effect of masking ............................................................................................................... 44
  3.3 Conditioned learning ................................................................................................................ 45
    3.3.1 Flavour-nutrient learning .................................................................................................. 46
    3.3.2 Flavour-flavour learning ................................................................................................... 49
4 NEOPHOBIA AND MERE EXPOSURE ...................................................................................... 51
  4.1 Neophobia .............................................................................................................................. 51
4.2 Mere exposure .......................................................................................................................... 53
  4.2.1 Effect of novelty and familiarity ........................................................................................ 54
  4.2.2 Factors influencing the effect of exposure ....................................................................... 55
  4.2.3 Frequency and number of exposures ............................................................................... 58
5 ROLE OF PERCEIVED COMPLEXITY ...................................................................................... 60
  5.1 Definition of complexity ....................................................................................................... 60
  5.2 Effect of stimulus complexity on the arousal potential ....................................................... 61
  5.3 Experience reduces perceived complexity ......................................................................... 62
  5.4 Designed complexity vs. perceived complexity .................................................................. 66
6 CHILDREN AS TEST PERSONS ................................................................................................. 69
  6.1 Recruitment ......................................................................................................................... 69
  6.2 Number of participants ....................................................................................................... 70
  6.3 Evaluation of childhood BMI .............................................................................................. 70
7 CONCLUSIONS AND FUTURE PERSPECTIVES .................................................................. 72
8 REFERENCES............................................................................................................................... 76
INTRODUCTION

The prevalence of overweight and obesity has increased dramatically worldwide over the last decades (WHO). In Denmark, the prevalence of overweight among children aged 4-18 years old has increased from 10.9% in 1995 to 14.4% in 2000-2002 implying that in only seven years, the amount of overweight children has increased with 40,000 (Matthiessen et al., 2008). Studies have shown that childhood overweight is associated with increased prevalence of hypertension, dyslipidemia and impaired glucose metabolism, the so-called metabolic syndrome (MS) (Campfield and Smith, 1999). Moreover, there is a tendency that overweight in childhood is tracked into adulthood (Haerens, Craeynest, Deforche, Maes, Cardon, and de Bourdeaudhuij, 2008) where it is also associated with a high risk of diseases as type II diabetes, high blood pressure, joint problems, sleep apnoea, and cardio-vascular diseases. The Danish society yearly spends approximately 14 billion Danish kroner on hospitalization and sickness absence caused by overweight (Indenrigs- og Sundhedsministeriet, 2007). In order to improve the quality of life and to subdue the costs of health care, effective weight loss strategies and knowledge about how to maintain a healthy body weight are required.

This is a challenge in industrialized countries where food supplies are generally ample and consistent. Here, overconsumption of energy dense foods and calories plays a significant role in the dysregulation of energy balance (Swinburn, Egger, and Raza, 1999). Therefore, a tremendous requirement for increasing the intake of healthy foods with lower calorie density exists. However, the healthy foods are only healthy when they are consumed and children’s food choice and intake is highly influenced by their liking or disliking of a food (Birch, 1979b; Liem and Mennella, 2002; Lowe, Horne, Tapper, Bowdery, and Egerton, 2004; Pangborn and Giovanni, 1984; Perez-Rodrigo, Ribas, Serra-Majem, and Aranceta, 2003). In light of discrepancies between recommended and actual food intake, the targeting of children’s food preferences to improve diets is believed to be a
more successful strategy compared to a strategy based on restrictions of foods (Horne, Lowe, Fleming, and Dowey, 1995; Lowe et al., 2004).

Even though some preferences are innate, most of them are learned during childhood and adolescence (Birch, 1998). Some argues that they show consistency over time (Nicklaus, Boggio, Chabanet, and Issanchou, 2004). However, studies have continually shown that it is possible to change children’s preferences by conditioned learning (Capaldi, 2001), mere exposure (Zandstra, de Graaf, Mela, and Van Staveren, 2000) and by increasing perceived complexity in the foods (Levy, MacRae, and Koester, 2006). A better understanding of children’s food preferences, their determinants and how they change over time are highly essential to change preferences in a more healthy direction. A more sustainable solution regarding children’s dietary habits is needed since availability and high appeal of healthy food is not sufficient to increase consumption. Hence, new strategies to change children’s food preferences are required and the main vision is to ensure children’s liking for healthier foods since liking predicts intake (Birch, 1979b; Drewnowski, 1997).

In this thesis, I hypothesize that it is possible to increase children’s preferences for healthier food products by changing children’s perception and preference of healthier foods. A second hypothesis is that food products can be altered in a healthier direction without a decline in children’s preferences. To succeed in changing children’s preferences, I hypothesize that changes in the food products should occur by a step-by-step change. When large product changes occur simultaneously, it may result in food neophobia and decreased preference as the product may become too novel, complex and intense (Levy et al., 2006).
Therefore, the overall aims within the present thesis are:

- To investigate how children’s food preferences can be changed step-by-step by modifying their preference and perception of healthier foods
- To study how food products can be changed step-by-step in a more healthy direction without loss in children’s food preferences

These overall aims involve modelling of children’s food preferences and foods simultaneously.

During this project focus has not been on an exact product type but on a large variety of food products since we aimed at developing various strategies to model food products in a more healthy direction. In this context ‘healthier foods’ are foods assigned to be reduced in sugar and fat content or increased in contents of fruit, fibres or grains. The figure below shows the research themes incorporated to fulfil the overall aims (Fig. 1). It is illustrated that changing children’s preferences for healthier foods involves modelling of both children’s food preferences and products. During this project it has been investigated if this change can be achieved by using mere exposure and by changing food complexity.

Fig. 1 An illustration of the research themes described in this PhD project
The specific aims are:

**Sub-aim 1:** To validate a method to assess children’s visual preferences using a picture-based conjoint layout.


**Sub-aim 2:** To establish knowledge on children’s visual preferences by using a picture-based conjoint layout and further to explore the influence of segmentation and selected background variables.

*(Paper 1-3)* – modelling of products.

**Sub-aim 3:** To establish knowledge on children’s taste preferences to make a starting point for further development of healthier foods and to define segments of children from selected background characteristics.

*(Paper 4-5)* – modelling children’s food preferences and products.

**Sub-aim 4:** To induce a change of children’s food preferences in a healthier direction


**Sub-aim 5:** To change foods step-by-step without loss in food preference

*(Paper 2-6)* -modelling children’s food preferences and products.

The target group is children aged 9-14 years old.
By fulfilling these sub-aims the present thesis will contribute with knowledge on how to evaluate and change children’s food preferences and how to change foods in a more healthy direction.

To achieve the specific sub-aims, the first studies were performed to validate a picture-based conjoint layout used for evaluation of children’s visual preferences (Paper1-2) and to investigate the factors affecting visual preferences (Paper 1-3). In concert these studies should elucidate if children make consistent food choices based on visual stimuli as appearance is the first sensation to arouse interest in food products (Gamble, Jaeger, and Harker, 2006; Jaeger and Macfie, 2001).

Secondly, we studied children’s taste preferences (Paper 4-5) to examine how they were altered during a step-by-step change in various sensory attributes. These studies make up a fundamental scientific basis for children’s taste preferences, liking and wanting to deliver on how much food products can be changed. Thirdly, the effect of mere exposure on changes in children’s liking was examined (Paper 6). In Paper 6 changes in children’s liking for fermented milk products with a step-by-step change in designed complexity was examined during mere exposure. For a schematic overview of the empirical design please see Fig. 2.

![Fig. 2 Schematic overview of the papers presented in this thesis.](image)

The undersigned author was the principal investigator in the studies described in Paper 2 and 4-6.
The overall purpose of this thesis is to discuss results obtained in the present studies in relation to established research. In chapter 1, the importance of studying both preferences, liking and wanting is discussed. Moreover, children’s sensory perception and how this is affected by sensory stimuli and various background characteristics will be described in this chapter. In chapter 2, differences in children’s sensory and cognitive development are addressed. Besides, a thorough review of the methods used in this PhD project and the challenges faced when conducting sensory evaluation with children are discussed. Then, a discussion on how children’s preferences can be changed during lifespan by using various methods of conditioned learning etc. is presented (chapter 3). In chapter 4, the role food neophobia and mere exposure will be highlighted according to changing of children’s preferences in a more healthy direction, and in chapter 5, the effect of increased perceived complexity on children’s liking will be discussed. Finally, chapter 6 briefly elucidates essential factors regarding children as target group in research within sensory science.
1 PREFERENCE, LIKING AND WANTING

The most significant drivers for food choice are preference, liking and wanting (Birch, 1979b; Drewnowski, 1997; Finlayson, King, and Blundell, 2007; Gibson, Wardle, and Watts, 1998). In sensory research, the terms ‘preference’ and ‘liking’ are often used interchangeably. In the present PhD project, it has been crucial to make a consistent distinction in terminology between ‘preferences’ and ‘liking’ in order to explore how children’s preferences, liking and wanting can be changed. This chapter deals with the terms ‘preference’, ‘liking’ and ‘wanting’.

1.1 Definition of terms

When reviewing existing literature, it is obvious that preference often is used as a synonym for liking in spite of the vital differences between the two terms (Mela, 2001; Lawless and Heymann, 1998). Preference is the selection of food over relevant alternatives including intrinsic and extrinsic factors. This may include liking and wanting, but also considerations of health values, brand, cost, convenience etc. Preference does not necessarily reflect liking; one option may be preferred over another option, even though neither is liked (Birch, 1999; Birch and Sullivan, 1991; Mela, 2001). In the strict behavioral sense, preference as choice implies nothing about the motivational process that leads to the choice (Birch and Sullivan, 1991). Liking, on the other hand, refers to an immediate qualitative, affective evaluation of a food (Rozin, 1989). Liking is judged against a personal reference scale for intensity and refers to the perceived attractiveness or aversion of specific objects and events within the immediate situation linked to a specific context and a present time frame (Mela, 2006). Research has indicated that not only liking but also wanting play an interdependent role in food choice and intake (Finlayson et al., 2007; Mela, 2006) which highlights the importance of a distinction between liking and wanting. Wanting is an incentive motivation that refers to an underlying implicit and objective drive process that can be seen as a directed impulse for a targeted
stimulus (Mela, 2006). Liking is a contributor to wanting, which presumably carries a component of anticipated pleasure, but liking is not enough to predict wanting (Mela, 2001).

To understand how changes in liking and wanting occur, the relative contribution of each component must be identified.

1.2 Dissociation of liking and wanting

It seems that humans can dissociate liking from wanting (Mela, 2006). In one of the present experiments (Paper 4 and 5), children’s liking and wanting for step-by-step changed apple juices, fruit drinks and fermented milk products (FMP) (named AMP in Paper 5) were evaluated using a 5 point hedonic facial scale. A very similar progression in liking and wanting with increased dry matter content in apple juice and fruit content in FMP was observed (see Fig. 3).

![Fig. 3 a) Mean ratings (n=195) of liking (♦) and wanting (■) of four apple juices with step-by-step changed dry matter content. b) Mean ratings (n=204 children) of liking (▲=LF, ●=HF) and wanting (■=LF, ♦=HF) of FMPs with stepwise changed fruit content.](image)

The mean rating scores for wanting were significantly lower than mean liking scores in both apple juice and FMP indicating that children liked the apple juice or FMP more than they wanted to drink it. Furthermore, a relatively high positive multivariate (PLSR) correlation (r=0.6) was found between liking and wanting in apple juices. However, the correlation coefficient showed that rating of wanting cannot be fully predicted by children’s liking. A further observation of the close
relationship between liking and wanting can be achieved by comparing the two PCA plot in Fig. 2ab and the two PLS plots in Fig. 4ab in Paper 4. The above mentioned results emphasize the importance of increasing both liking and wanting to obtain healthier food choices. It may be that liking for the specific food is high, but if wanting is low, the food will probably not be consumed, e.g., you may like sushi, but you do not want to eat it for breakfast. Wanting is highly related to contextual factors in which the food is served (Cardello, 2000), and therefore food appropriateness and eating situation are very essential to increase wanting. Therefore, to ensure a healthy food choice among children, wanting must be increased as well.

Finlayson et al. (2007) stated that it may be a problem to use similar forms for measurement of liking and wanting, sequentially. These authors argued that if an individual perceives liking and wanting as the same question, they might adjust their responses to be consistent and avoid dissonance. In the present study, the similar scales used for evaluation of both liking and wanting within a short time interval may have biased the results (Paper 4-5). However, when testing children, usage of three different methods to evaluate preference, liking and wanting may have caused confusion, especially among the youngest children. Moreover, the Danish terms for liking (‘at kunne lide’) and wanting (‘at have lyst til’) are assessed to be relatively easily differentiated by children. Liem and Zandstra (2009) used three different scales to evaluate development of children’s preferences, liking and wanting of different shaped snack products during mere exposure. Preference was measured by means of a rank-order method, liking on a 5-point hedonic facial scale and wanting was evaluated on a 5-point category scale. The results from this study showed that liking for small shaped snacks remained stable during mere exposure whereas large shaped snacks decreased in liking. Mean wanting decreased during mere exposure, which indicates that wanting rather than liking was most affected by mere exposure. Finlayson et al. (2007) asked adults to indicate on a line scale how pleasant it would be to taste a specific food, in order to assess liking.
Moreover, a forced-choice photographic methodology designed and performed using a computer was adopted to assess wanting. They measured liking and wanting pre- and post-consumption, and the results indicated a state dependent distinction between liking and wanting since more differences in liking and wanting were observed when hungry than when satiated. It has previously been suggested that wanting depends on contextual factors such as the perceived appropriateness of consumption of foods and the context in which the food is served (Mela, 2006). Wanting can therefore fluctuate depending on the context in which the food is served whereas liking, has been shown to be more stable (Liem et al., 2009; Nicklaus, Boggio, and Issanchou, 2005).

A promising approach to evaluate wanting includes tasks in which individuals have to perform certain instrumental response to evaluate wanting as performed by Epstein, Truesdale, Wojcik, Paluch, and Raynor (2003) and Havermans, Janssen, Giesen, Roefs, and Jansen (2009). The participants in the study conducted by Havermans et al. (2009) were asked to evaluate pleasantness of taste and smell of chocolate milk and crisps. Afterwards, they were enrolled in a computer game to evaluate the degree of motivation (wanting) to work for more chocolate milk or crisps. Such a computer game could be an alternative to the classic rating procedure described above; also in evaluation of children’s wanting.

Evaluation of both liking and wanting determines two essential drivers for food choice, but further research is required as it may improve our understanding of food choice, weight regulation and the etiology of obesity in particular. In many public health campaigns, the aim is to alter food choices towards more healthy food but often healthy foods are less liked and/or less wanted. This fact alone positions the understanding and ability to guide liking and wanting as a central challenge to consumer research (Mela, 2006).
1.3 Factors influencing children’s food preferences

As previously stated, children’s food preferences are of interest because they have been assumed to have a profound impact on food choice and intake. Research has repeatedly shown that children’s food preferences are highly predictive for their intake (Baxter and Thompson, 2002; Birch, 1979b; Birch and Sullivan, 1991; Domel et al., 1993; Domel et al, 1996; Fisher and Birch, 1995; Gibson et al., 1998; Resnicow et al., 1997). This is presumably because children are less concerned about external factors such as cost and nutrient density which is known to affect adults’ consumption patterns. However, children’s food preferences and food choices are influenced by various food related, person related and environmental factors as shown in Fig. 4. All factors are essential but the significance of a factor varies according to the specific situation and life stage of the individual child. Most of the factors illustrated in Fig. 4 will be elucidated in this thesis.

**Fig. 4** Overview of factors influencing children’s food preferences and food choices (adapted from Shepherd and Pro-children framework (Shepherd (1989))).
Information about the relationship between food preference and food choice is essential to our understanding of the role of preference in children’s eating patterns. Birch (1979b) found that sandwiches with a high ranking score were consumed in larger amounts than sandwiches with low ranking score, and a significant relationship between preference and intake of fruit and vegetable was also observed by Eriksen, Haraldsdottir, Pederson and Flyger (2003) and Resnicow et al. (1997). We investigated the relationship between children’s liking and intake of apple juice varying in colour and acid concentration during an exposure period (results unpublished – for study description see chapter 4). Children were asked to rate liking of four various apple juices varying in sourness and colour on a 5-point hedonic facial scale pre, midway and post exposure and intake of each child was registered each day during the exposure period. Fig. 5 shows the regression between intake and liking from the first rating test of liking and it indicates that intake increases with liking. The figure shows that data around low levels of liking (1, 2 and 3) are more scattered whereas data of high levels of liking (4 and 5) are centered more on the mean.

Fig. 5 shows the regression between intake and liking of apple juice among 107 children (unpublished results).
These results add to the existing knowledge that liking and food choice are associated thus, when changing children’s food choices, liking must be changed as well.

1.3.1 Visual preferences

Research has shown that also children’s visual preferences are important drivers for food choice (Leon, Couronne, Marcuz, and Koster, 1999; Marshall, Stuart, and Bell, 2006). Appearance is the first sensation to arouse interest in a given food (Lawless, 2000) and it sets up expectations for the actual sensory perceptions (Gamble et al., 2006; Jaeger and MacFie, 2001; Leon et al., 1999). In Paper 1 and 2, the aim was to elucidate the relationship between children’s visual preferences and food choice by using a picture-based conjoint layout. Children were asked to make an incomplete ranking of pictures of various products (bread, juice, yoghurt and smoothies) and as a final point they were asked to perform an actual product choice of tangible products. Results from Paper 2 illustrated that children visually preferred smoothies without visible fruit compared to smoothies with visible fruit which was also the case in the actual choice test of tangible products ($r=0.82$, $p=0.002$) (see Table 9, Paper 2). Similar results were achieved in Paper 1. This study showed that children who visually preferred a dark brown bun in the picture-based conjoint layout also selected a dark brown bun in the actual choice test ($p<0.0001$) (see Table 5 and 6, Paper 1). The conclusions of the two studies were that visual preferences are highly predictive for food choice which highlights the importance of food appearance in the modification of children’s preferences. Calfas, Sallis and Nader (1991) assessed preferences for healthy and unhealthy foods in 3-8 year old children using photographs, and their results also showed a high correlation ($r=0.70$) between preferences and actual food choice. Similar results for children were seen in a study by Jaramillo et al. (2006) and for adults in studies by Gamble et al. (2006), Reisfelt, Gabrielsen, Aaslyng, Bjerre
and Moller (2009), Jaeger, Hedderly, and MacFie (2001) and Brunso, Bredahl, Grunert, and Scholderer (2005). These results will be further elaborated in chapter 2.

In the study described in Paper 3 the picture-based conjoint layout was used to evaluate visual preferences of various fruit and vegetable mixes. Besides the evaluation of visual preferences for the fruit and vegetable mixes, liking of the mixes was also evaluated. The results showed that visual preferences were affected by overall liking in both adults and adolescents (p<0.05) (see Table 3, Paper 3). Many of the effects of liking seemed obvious, such as preferring mixes with grapes when liking grapes. In the study described in Paper 1 children were also asked to rate liking of visual preference. A relatively high reliability of visual preferences from the picture-based conjoint layout and hedonic liking scores from the rating test on visual appearance was found for most product attribute estimates (see Table 3-4, Paper 1). Together, these results stress the importance of measuring the effect of liking when evaluating visual preferences.

1.3.2 Taste preferences

The study on visual preferences for bread described above illustrated that children in general preferred the light bun over the dark bun (Fig. 2, Paper 1) which was further supported in a study by Bakke and Vickers (2007). They found that children selected refined bread 5 times more often than whole-grain bread. Unfortunately, the foods that children like the most are rarely of high nutritional value (Cooke, Wardle, 2005). Studies investigating children’s preferences have found that fatty and sugary foods feature heavily in children’s top10 over liked foods (Bellisle, Rolland-Cachera, and KSACCN, 2000; Diehl, 1999; Skinner, Carruth, Bounds, and Ziegler, 2002; Wardle, Sanderson, Gibson, and Rapoport, 2001). Cooke and Wardle (2005) found that vegetables were over-represented in the lowest rated foods, but that grapes and strawberries were included in the ‘top 10’ list. These results are found to be valid on a cross-cultural basis (Diehl, 1999; Gibson et al.,
1998; Perez-Rodrigo, Ribas, Serra-Majem, and Aranceta, 2003; Skinner et al., 2002) and are furthermore in consistency with the evidence for an innate predisposition to prefer very sweet tastes. However, research shows that children develop their preferences during maturation when they are exposed to a variety of food items, textures, taste and flavors (Birch, 1999). Results from a study conducted in this PhD project (Paper 4) investigating children’s preferences, liking and wanting for apple juices varying in dry matter content confirmed a positive relationship between preference and dry matter content. However, this relationship was only true until the dry matter content had reached a certain level (15.5 g dry matter/100 ml apple juice) where after preferences stabilized even though dry matter content continued to increase (see Fig. 1, Paper 4). This result is crucial in development of healthier food products to children as it seems that an upper level in children’s preferences according to sweetness exists. Additionally, this study revealed a segment of children who preferred apple juices with lowest dry matter content (less sweet), sour fruits and sour candy (see Fig. 4a, Paper 4). The presence of a segment among children who prefers sour tasting food products is supported by results from Liem and Menella (2003). They also observed a segment of children preferring extreme sour tastes. These children tended to consume a greater variety of fruits when compared to other children (p=0.11) and the preferences for sour tastes generalized to other foods, such as candies and lemons. Preference for sour taste could therefore play an important role in the consumption of sour-tasting fruits and maybe fruits in general. Therefore, it is relevant to explore the possibility of changing children’s preferences towards an acceptance of more sour food products (Moskowitz, Kumaraiah, Sharma, Jacobs, and Sharma, 1975). Liem and Menella (2003) also found that children with high preference for extreme sour tastes were significantly less food neophobic (p<0.05) compared to other children. Children with less food neophobia are more willing to try new foods (Pliner and Stallberg-White, 2000) and Pliner and Stallberg-White (2000) have shown that mere exposure to foods can change preferences for that specific food. Therefore, it is
hypothesized that less food neophobic children are more likely to experience extremely sour foods and as a consequence of mere exposure develop preferences for such flavors (Birch, Gunder, Grimm-Thomas, and Laing, 1998; Birch and Marlin, 1982; Pliner and Stallberg-White, 2000) and sour fruits and fruits in general. For our future research, it would be very interesting to study if the segment of children who preferred the apple juice with lowest dry matter content (less sweet) (Paper 4) also prefers other sour tasting food products than sour fruits and candies.

Previous research on children revealed that mere exposure to sour flavors may lead to subsequent preferences (Liem and Mennella, 2002; Mennella and Beauchamp, 2002). Children who were fed a formula (protein hydrolysate formulas) that has a sour and bitter flavor component during infancy preferred sour-flavored juices significantly more than did children who were not exposed to such formulas (Mennella and Beauchamp, 2002). Similar findings are seen among Indian laborers whose diet consists of many sour foods such as tamarind fruits. They preferred higher levels of citric acid in water when compared to those living in western populations whose diet had less of an emphasis on sour foods (Moskowitz et al., 1975).

Segmentation of children according to taste preferences is not only seen for sourness. Research has provided evidence for a biochemical basis for some individuals with high sensitivity to the bitter tastant 6-n-propylthiouracil (PROP) being indicative of lower liking for bitter foods (Anliker, Bartoshuk, Ferris, and Hooks, 1991). PROP has especially been proved to influence children’s preferences for vegetables, especially cruciferous vegetables (Drewnowski and Hann, 1999). These results indicate that it is highly relevant to change children’s preferences and liking for more sour and bitter foods as this may lead to a higher intake of healthy foods.
1.4 Gender, age and ethnical differences in food preferences

Several studies have shown that intake and eating patterns were very similar for boys and girls (Domel et al., 1993; Domel et al., 1996; Lytle, Seifert, Greenstein, and McGovern, 2000; Perez-Rodrigo et al., 2003). However, a review of studies on determinants of children’s fruit and vegetable intake stated that gender was among the strongest determinants of children’s fruit and vegetable intake. In 14 of 17 European studies, girls reported to eat more fruit and vegetables than boys (Rasmussen et al., 2006). One study on 4-5 year old British children showed that girls liked vegetables more than boys, but no gender differences in liking were observed in other food categories (Wardle et al., 2001). The same trend was observed in a French study with 9-11 year-olds (Le Bigot Macaux, 2001), American children and adolescents (Reynolds et al., 1999), German 10-14 year-olds (Diehl, 1999), and Norwegian 16-21 year-olds (Lien, Lytle, and Klepp, 2001).

Moreover, Wardle et al. (2004) found that liking for fatty and sugary foods, meat, processed products and eggs was higher for boys compared to girls, whereas no gender differences in liking for foods in the fish, dairy or starchy staples categories were found. These conclusions may be a result of a larger energy requirement for boys compared to that of girls, and that a higher liking for energy-dense foods thereby serves an adaptive purpose. In contrast, social desirability is believed to have a stronger impact on girls’ food intake as they often attach to diets which results in a lower energy intake. In some of the studies presented in this thesis, differences in preference, liking and wanting according to gender were also observed. The study on preference, liking and wanting of FMP varying in fat- and fruit content (Paper 5) showed that girls preferred low fat FMP with 20% over low fat FMP with 5% fruit, but they did not perceive any difference in sourness. Contrary, boys preferred the FMPs equal but they perceived high fat FMP containing 20% fruit as more sour than high fat FMP with 5% fruit, see Table 1.
Moreover, the results from a $\chi^2$ test added the PARAFAC analysis showed that the segment of children which liked and wanted FMPs with low fat and fruit content was to a greater extent composed of girls than boys (see Fig. 2 and 3, Paper 5). This is consistent with the fact that more girls than boys attach to diet. The same study also examined preference, liking and wanting for various apple juices and fruit drinks (Paper 4). Here, the results showed that girls accepted a lower dry matter content compared to boys, they liked and wanted sour juices, sour fruit and sour candy more than boys and their consumption of fruit was low compared to boys (see Fig 4ab, Paper 4).

-Age is another factor which influences children’s liking. In more of the studies conducted in this PhD thesis, age differences in children’s food likings were observed. One study indicated that fruit and vegetables intake increased with age (see Fig. 4a, Paper 4), and another study showed that the segment of children, who liked and wanted the FMP with high fat and low fruit content, was to a higher extent composed of older children (13-14 year-old) (Paper 5).

Age differences in visual preferences were also observed in the present thesis. In the study on children’s visual preferences examined using the picture-based conjoint layout various demographic variables were included as well (Paper 2). Fig. 6 shows a PCA plot of the incomplete ranking scores of smoothies and yoghurts and various selected demographic variables. In sensory research multivariate data analysis is usually performed on rating data as ranking data may not give a direct estimate of the size of any difference in preference. However, Markussen (2008) made multivariate data analysis on incomplete ranking and his results illustrate the relations between preference data and background variables very well. In the present thesis, the multivariate analysis on ranking data
supports the univariate data analysis. The PCA plot shown in Fig. 6 indicates that the oldest age group (6th graders) accepted more novel and complex smoothies and yoghurts compared to the youngest age group (3rd graders). This result is supported by the results from the univariate analysis (Table 7, Paper 2). The age relevance associated with food intake has been verified by Cooke and Wardle (2005) who also found age-related differences in food preferences by showing that liking for fruits and fatty/sugary foods reached a peak at 8-11 years, whereas liking for fish and dairy foods was highest among the youngest children and declined thereafter. Preferences are in general modified by developmental changes, experience and learning during childhood and adolescence. Nu, MacLeod, and Barthelemy (1996) proved that large changes in preferences appear around puberty as a ‘Widening of the food repertoire’ occurs when food neophobia is reduced and an increase in autonomy and in eating out independency arises. Differences in the peripheral sensory receptors or central affective signals also arise during maturation (Mela, 2001). These findings indicate a need for future studies on children’s food preferences that spans the transition from childhood to adolescence.

The last factor affecting children’s preferences covered in this section is the influence of ethnicity. When examining children’s visual preferences some ethnical differences were observed (Table 7, Paper 2). The PCA plot illustrated in Fig. 6 shows that children with another ethnic background than Danish visually preferred more novel and complex smoothies and yoghurts than ethnic Danish children.
Two studies exploring the importance of ethnical origin in relation to children’s food preferences are identified. Reynolds et al. (1999) found ethnical differences related to food intake in two states, Georgia and Minnesota, in the US. In Georgia, they found that African-Americans generally ate more fruit and more fruit and vegetables combined than European-Americans. In Minnesota, Asian-Americans/Pacific Islanders and African-Americans ate more fruit than European-Americans; and European-Americans and African-Americans ate more vegetables than Asian-Americans.

Krebssmith et al. (1996) found that children in other ethnical categories than native Americans consumed the highest number of servings of fruit and vegetables per day with African-Americans and European-Americans eating the highest number and Hispanics the fewest servings. These results clearly show that various segments within the group of children exist and that these children have various food preferences.
In summary, children’s food preferences are influenced by several factors which are essential in the change of children’s preferences. Food preference, liking and wanting is crucial determinants of children’s food choice and therefore important when aiming to increase intake of healthy foods. Children prefer sweet foods until a certain limit but segments of children liking and wanting sour and bitter tasting foods exist. Changing children’s preferences, liking and wanting into a direction where more sour and bitter foods are accepted may increase the intake of healthy foods.
2 SENSORY EVALUATION WITH CHILDREN

Children of today compose a large consumer segment (Popper and Kroll, 2005a) that are more involved in choosing what to buy and eat than ever before (Chambers, 2005). The number of food products targeted children has increased tremendously and new product developers are struggling to understand what excites the palates of this consumer segment. Sensory evaluation with children has consequently become extremely important both in research and in the food industry. However, reviewing the scientific literature on sensory testing of foods reveals that much of the established knowledge arises from studies involving only adults. Kroll (1990) noted that “testing with children is in an embryonic stage”. Since then, sensory evaluation with children has become more pronounced and among researchers it has been emphasized that only children are real representatives when food products targeted towards children are to be tested (Moskowitz, 1985). Using children in sensory evaluation of foods poses new challenges compared to sensory evaluation with adults as many factors are influencing the sensory evaluation process (see Fig. 7). This chapter addresses some of the pragmatics of sensory evaluations of foods with children. I will focus on the factors and challenges important for the research we conducted during this project. This includes differences in children’s sensory and cognitive developmental stages, challenges in the methodologies used in sensory evaluation with children, and various factors influencing sensory evaluation with children as illustrated in Fig. 7.
2.1 Sensory development in children

When designing and performing tests with children, it is of utmost importance to be aware of the information one want to obtain and which information children are capable of providing. Children mature differently as their senses are not fully and equally developed. Research on vision and auditory skills suggests that children react to tones and light as much as adults do (Moskowitz, 1985), while information about the development of children’s chemical senses, taste, and smell is inadequate. Darwin (1877) observed that children live in a different chemical sensory world than adults evidenced by their higher preference for sweet and sour tasting foods. It is known that as people get older the threshold of stimuli needed to excite taste sensations increases. Knowledge of taste sensitivity (at threshold and supra threshold levels) in infants, very young children and elder subjects is substantial, but only little information on the taste sensitivity of children and adolescents exists. Some studies have reported that children aged 5-7 and 8-9 years old have detection thresholds similar to that of adults (Anliker et al., 1991; James, Laing, Jinks, Oram, and
Results from the study by James et al. (2004) indicated an equal sweetness response between adults and 8-9 year old children which implies that sweetness sensitivity reaches maturity by mid-childhood. However, the majority of studies have found that children have lower taste sensitivity than adults (Glanville, Kaplan, and Fischer, 1964; James, Laing, and Oram, 1997; Mela, 2001). This is caused by the fact that children simply require higher levels of e.g. sweetness within foods to achieve the same perception of sweetness intensity compared to adults. Zandstra and de Graff (1998) showed that with increasing sucrose concentration the perception of sweetness increased by a lower gradient in children aged 6-12 years old compared to older children and adults. The results mentioned above indicate that significant changes occur in taste sensitivity across a life span which emphasizes the importance of sensory evaluation with children. Determination of children’s taste sensitivity is complicated, as the evaluation of sensory perception in children is a challenge due to many confounding factors (Fig. 7). Knof, Lanfer, Bildstein, Buchecker, and Hilz (2011) has recently shown that it is possible to assess taste sensitivity in children by using a board game to measure taste sensitivity but future studies are needed on taste sensitivity in children and adolescents.

2.2 Cognitive development stage

The cognitive development of children depends on the developmental stage of the individual child since children mature mentally and physically at their own rate (Popper and Kroll, 2005). Therefore, when conducting sensory evaluation with children the researcher must be prepared for children to be at different stages of cognitive development. I have chosen to focus on the cognitive challenges related to the target group; children aged 9-14 years, included in our studies. ‘The ASTM committee 18 on sensory evaluation’ has compiled children’s cognitive abilities as a
function of age as shown in Table 2 (Guinard, 2001). The table provides an overview of children’s
cognitive skills and the appropriate sensory methods for children from infancy to teens.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Cognitive skills of children from infancy to teenage (from ASTM committee 18 on sensory evaluation (Guinard, 2001))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skill/Behaviour</td>
<td>Infant Birth-18 months</td>
</tr>
<tr>
<td>Language—Verbal, reading, written language, vocabulary</td>
<td>Pre-verbal, rely on facial expressions, cannot read, cannot write, use sounds, very few words</td>
</tr>
<tr>
<td>Attention span</td>
<td>Caused by eye contact</td>
</tr>
<tr>
<td>Reasoning</td>
<td>Limited to paired and pleasure, limited, but concept of ‘no’ becoming a factor</td>
</tr>
<tr>
<td>Decision making</td>
<td>Does not make complex decisions</td>
</tr>
<tr>
<td>Understanding scales</td>
<td>Does not understand scales</td>
</tr>
<tr>
<td>Motor skills</td>
<td>Possesses some gross motor skills, no fine motor skills</td>
</tr>
<tr>
<td>Recommended evaluation techniques</td>
<td>Behavioral observations, statics, consumption or duration measurements</td>
</tr>
</tbody>
</table>

To manage the challenges concerning variability in cognitive development and maturity among
children it is necessary to make a thorough and targeted introduction to the test methodology. The
researcher must ensure fully comprehension among children to obtain reliable results (Moskowitz,
1985; Guinard, 2001). It is important that special consideration is given to the phrasing of the
questions and the vocabulary used as some children might have difficulties in reading and
comprehension tasks (Table 2). In all studies presented in this thesis, a very thorough introduction
to the tests was given. In one of the studies, the introduction was made several days prior to the real
experiment began (Paper 6) whereas the introduction was given on the test day in other studies (Paper 1-5). In all cases specific emphasis was placed on the fact that the instructor used a ‘child-friendly’ phrasing to ensure comprehension and to hold interest, and children were informed that no right and wrong answers exists to minimize social desirability (Table 2). To ensure exactly the same explanations and phrasings to all children, it was the same instructor who introduced the experiment in all groups. Providing the introduction on a separate day is preferred as it allows time for explanations and questions and children becomes familiarized with the research team.

In the introduction, special attention was given to the explanation of the hedonic facial scales as some of the youngest children may have difficulties with the abstract nature of symbols and pictures (Popper and Kroll, 2005). For instance, some subjects may respond to smiley faces based on what they show (a happy face) rather than based on what they are supposed to represent (how the food makes you feel). One might argue that the children in our target group were old enough to fully understand and use the hedonic facial scales as indicated in Table 2. However, skills and stage of cognitive development in this age span differ notably, and we experienced a need for a thorough explanation of the facial scale among a substantial part of the youngest children (9-10 years old).

Findings of Gollick (2002) support the large span in skills among children at same age. He showed that the age at which 10% of children can master a particular task compared to the age at which 90% of children can do so varies by as much as 4 years. Thus, assumptions regarding what particular age groups can manage are often only approximations and researchers need to take the considerable variation in children’s abilities into account.

Other methods that have been used to ensure comprehension among children are group demonstrations, warm-up exercises on the procedure (Birch and Sullivan, 1991; Guinard, 2001) or to conduct a preliminary study on a simple stimulus. The study reviewed in Paper 6 describes a preliminary study performed in this PhD project. In this study, children were asked to rate one or
more stimuli to ensure their understanding of the rating procedure and the hedonic facial scales. Additionally, a preliminary study reveals hidden challenges which can emerge when children are tested.

2.3 Methodology for sensory evaluation with children

Despite the difficulty in using children for sensory evaluation, it is important to obtain information about children’s preferences, perceptions, liking and wanting for foods. Using children as assessors in sensory evaluation provides valuable results in fundamental sensory science and in product development (Guinard, 2001; Hough, Sanchez, Barbieri, and Martinez, 1997; Ward, Koeferli, Schwegler, Schaeppi, and Plemmons, 1999). Results investigating reproducibility and validity of children’s preferences are found to show a relatively high degree of stability in their preferences (test-retest correlation r=0.58 and r=0.70) (Calfas et al. 1991). A good agreement between measured preferences and actual food choices (66%) was observed which supports the results from our studies (Paper 1-2). Summing up, these results demonstrate that evaluations of food preferences among children are reliable.

Several sensory methods are appropriate for research on children, and in the following sections, focus will be on the methods used in the experiments performed in this project.

2.3.1 Rating of liking

One method used to evaluate liking and acceptance is the rating test. In hedonic rating tests, products are evaluated monadically on a line scale or an interval scale such as e.g. a facial hedonic scale, and the food is judged for its liking. The most common hedonic scale is the 9-point hedonic scale, but other numbers of categories have been used as well; the 7-point hedonic facial scale introduced by Chen, Resurreccion, and Paguio (1996) or the 5-point hedonic facial scale used by
Thybo, Kuhn and Martens (2004), Leon et al. (1999) and Zandstra and de Graff (1998). For illustration of the hedonic scales used in this project please see Fig. 8.

**Fig. 8** Examples of two different hedonic facial scales used for rating of liking in the present thesis. a) self-designed, b) (Chen et al., 1996).

The number of categories of the scale used for rating tests must be determined from age and cognitive skills of the children. As children tend to avoid the extreme ends, reducing the scale to very few categories may be inappropriate (Lawless and Heymann 1998). In this project, we used the hedonic facial scales to assess children’s liking. In three studies (*Paper 1, 4-5*), the 5-point hedonic
facial scale was used, whereas the 7-point hedonic facial scale was used in the study described in Paper 3 and 6.

For many products liking are situated in the intermediate area and a 7-point hedonic facial scale allows a better separation of the levels of liking than does a 5-point hedonic facial scale. When children are able to use the 7-point hedonic facial scale, we recommend the use of this scale to ensure a better grading of liking. The hedonic facial scales have been used and validated as a reliable method to assess children’s liking of food products by several researchers. Leon et al. (1999) showed that children older than 5 years were capable of using a 5-point hedonic facial scale when instructed appropriately. Kimmel, Sigmangrant, and Guinard (1994) demonstrated that children until the age of 4 years and older were able to use the 7-point hedonic facial scale added anchors to express their degree of liking. Others have used the 7-point facial hedonic scale with anchors (7= “super good” to 1= “super bad”) or a hedonic scale solely anchored with words to report liking in children (Allison, Gualtieri, and Craig-Petsinger, 2004; Chen et al., 1996; Pagliarini, Gabbiadini, and Ratti, 2005). Kroll (1990) applied three different scales to evaluate liking in children aged 5-10 years old. He used a standard hedonic scale, a facial scale and a child-oriented verbal scale named Peryam and Kroll scale (P&K-scale). He concluded that the P&K-scale performed better than the hedonic and the facial scale (see further description page 33). These results prove that children are capable of using the hedonic scales to evaluate liking as long as they get an appropriate introduction.

More advantages are related to the use of hedonic scales in rating of liking including easiness of use and simplicity (Stone and Sidel, 1985). Of disadvantages Moskowitz (1985) mentioned that the hedonic scale might not be quite equally spaced, the neutral category makes the scale less efficient, and many consumers tend to avoid the extreme categories. The neutral response category is considered important as it is a valid reaction to products for some individuals, and although many
consumer evaluations show ‘end use avoidance’, this is generally not a problem when using children as assessors. Children are often frequent users of the positive end of the scale and tend to avoid the negative end (Moskowitz, 1994). This indicates that children assign a more narrow range of hedonic evaluation compared to adults which may result in too optimistic results. In the present project a study on the effect of mere exposure to apple juice varying in colour and acid concentration on 9-11 year old children’s liking was conducted (unpublished results- for a study description please see chapter 4). In this study it was observed that the mean ratings of the yellow apple juices were very high; approximately 4.5 on a 5-point hedonic scale. This supports the statement that a majority of children use the positive end of the hedonic scale. The apple juices used in this exposure study were very sour and were expected a noticeably lower rating of liking based on existing theory of children’s preferences for sour foods. However, other factors such as social desirability and ‘a break in the teaching’ may have contributed to the high rating scores as well. In Paper 6, the 7-point hedonic facial scale was used to rate liking and the children participating were of a broader age range. This study showed that children were less prone to the use of the positive extremes and that mean ratings were intermediate (see Fig. 1, Paper 6). Another issue to be addressed is how the faces used in the hedonic facial scales communicate the basic idea. Cooper (2002) argued that a sad face intended to illustrate a degree of “dislike” can be interpreted by a child as saying “I am angry”. This leads to inappropriate results as the child might not feel anger in response to the food and would subsequently avoid using the ‘sad face’ even though the product is disliked.

Despite the above mentioned challenges, the hedonic facial scales are popular in testing with children based on the rationale that younger children may have difficulties in reading and may not fully understand complex words or phrases. They can more accurately deal with facial expressions
and additionally pictures are entertaining and thought to inspire closer attention to the task (Kroll, 1990) (Table 2).

The sensory methods used for sensory testing with children must continuously be evaluated and validated to determine at what age they can be used. Children are maturing earlier and the cognitive demands and processing skills to meet those demands have changed. More research should be applied to the development of sensory methods adapted to certain age groups. A good example of an adaptation of the hedonic scale is the P&K scale developed in 1990 (Kroll, 1990). The P&K scale is similar to the traditional 9-point hedonic scale, but the verbal anchors associated with the scale are more child-friendly. Instead of using the terms “like extremely” and “dislike extremely” it employs the terms “super good“ and “super bad”. Others have used anchors as “yummy” and “yucky” (Shapera, Moel, Kamath, Olson, and Beauchamp, 1986). Alterations in the everyday language together with the increased global focus on many product categories implies a requirement for continuous revalidation and updating of sensory methods and techniques which highly depend on use of vocabulary.

2.3.2 Ranking of taste preference

In ranking tests, individuals are asked to rank products in either descending or ascending order of preference. Ranking is a forced choice procedure that requires individuals to judge foods against each other. Examples of ranking are ‘best-worst ranking’, incomplete ranking, and full ranking (Lawless and Heymann, 1998). Rankings do not give a direct estimate of the size of any difference in preference although it is possible to derive some Thustonian scale values from the proportions. The data are ordinal and therefore treated as nonparametric. Ranking is intuitively simple for the individuals, and due to its simplicity ranking may be an appropriate choice in testing with children.
who have difficulties in understanding scaling instructions (Coetzee and Taylor, 1996). Ranking can be done quickly and with relatively little effort.

The ranking procedure was also used in the present project (Paper 4-5). In this study, children were asked to rank preference and perception of sourness intensity for four apple juices and four fruit drinks varying step-by-step in dry matter (see Fig. 1, Paper 4). Additionally, children were asked to rank four fermented milk products (FMP) (named AMP in Paper 5) varying step-by-step in fat content and fruit concentration (Fig. 1, Paper 5). The results showed that children were capable to rank the products according to preference and sourness. After completing the study, twelve children were asked to repeat the ranking tests of all four products and a high reproducibility was observed in general. The results from the repeatability test on apple juice are displayed in the PCA plot (Fig. 9). Equal symbols represent the result of the first and the second ranking test of the apple juice for one child, respectively. Symbols positioned close together indicate high reproducibility between first and second ranking test. In general, the PCA plot shows a high reproducibility of the ranking test since most symbols are positioned relatively close together.

Fig. 9 Children’s (n=12) ability to repeat the ranking tests (n=2) of preference for apple juice, analysed by Principal Component Analysis (PCA). Equal symbols represent the result of the first and the second ranking test of the apple juice for one child, respectively. Symbols positioned close together indicate high reproducibility between first and second ranking test.
Several other studies evaluated children’s preferences by using ranking procedures (Birch, 1979a; Birch, 1979b; Birch, Mcphee, Steinberg, and Sullivan, 1990; Birch and Sullivan, 1991; Birch, Zimmerman, and Hind, 1980; Kimmel et al., 1994; Liem and Mennella, 2003; Liem, Westerbeek, Wolterink, Kok, and de Graaf, 2004). Liem et al. (2004) investigated sour taste preferences of children aged 7-12 years old. They used a rank-order procedure for preference and showed that children in this age span were capable to rank preference for sour taste in four gelatines varying in degree of sourness. Results from Kimmel et al. (1994) and Birch et al. (1990) further illustrated that the ranking procedure can be used by children until 4 years old with reliable and reproducible outcomes.

2.3.3 Ranking of visual preferences

The ranking procedure most often involves actual tasting of foods to assess preferences. This approach is associated with certain advantages or disadvantages. One of the advantages is that tasting of foods produces high predictive validity with respect to choice and intake patterns. The disadvantages are that use of actual food products as stimuli becomes tedious, expensive, and poses certain logistic challenges especially in consumer studies including large numbers of children and foods items. Moreover, children can only taste a limited amount of foods before getting satiated, which might affect the results. Use of stimuli other than actual foods allows researchers to obtain information on more foods items and from a larger group of children without additional investment of resources. Therefore, an alternative to rank taste preferences for actual foods is to rank visual preferences for foods, food models, pictures and drawings of food (Calfas et al., 1991; Guthrie, Rapoport, and Wardle, 2000). As stated previously, visual stimuli are a strong driver of food choice (Moskowitz, 1994) why food appearance is a predictor whether the food will be eaten or not (Rolls, Rowe, and Rolls, 1982). In three of our studies, children’s visual preferences for buns and juice
(Paper 1), yoghurts and smoothies (Paper 2) and fruit and vegetables mixes (Paper 3), respectively, were examined using a picture-based conjoint layout. In the study described in Paper 1, children performed the incomplete ranking of buns and juices twice and the results showed high reproducibility between the two test days for most product attribute estimates. The overall correlation coefficients for buns were: Colour: 0.76 (p<0.0001), butter: 0.63 (p<0.0001), pattern: 0.39 (p<0.0001), topping: 0.51 (p<0.0001) and seeds: 0.51 (p<0.0001). As mentioned before children in both Papers 1-2 were asked to make an actual choice of tangible product and results from Paper 2 showed that 135 children (50.2%) choose exactly the same smoothie in the picture-based conjoint layout and the actual choice test. Fig. 10 shows an example of the pictures presented in the picture-based conjoint layout (A) and the presentation of the smoothies from the actual choice test (B), respectively.

![Fig. 10](image1)

**Fig. 10** a) Screen dump example of the eight smoothies from the picture-based conjoint layout. b) Presentation of the eight smoothies in the actual choice test.

Several researchers have successfully used pictures to evaluate drivers for food choice in both adults (Brunso et al., 2005; Deliza, MacFie, and Hedderley, 2003; Gamble et al., 2006; Mahanna
and Lee, 2010; Mahanna, Moskowitz, and Lee, 2009; Munkevik, Hall, and Duckett, 2007; Ngapo, Martin, and Dransfield, 2007; Reisfelt et al., 2009; Jaeger et al., 2001) and children (Calfas et al., 1991; Guthrie et al., 2000; Jaramillo et al., 2006). Gamble et al. (2006) have used a choice-based conjoint study using pictures to assess adult consumer's preferences for appearance in pears differing in shape, colour and russet. They found that adult consumers preferred pears with green and yellow colours with intermediate-straight or elongate-concave shapes. Further analysis of choices suggested that consumers respond in terms of familiarity with existing pears. Jaramillo et al. (2006) studied children's preferences for fruits and vegetables using hedonic evaluations of pictures on a computer screen. The results showed high reliability ($r=0.73$) and the predictive validity based on both observations and measurement of plate waste showed good agreement between preferences and observed intake. In a study by Guthrie et al. (2000), they used three different stimuli modalities to compare reliability of food preferences (test-retest) in 3-5 year old children. They found that pictures displayed high reliability ($r=0.75$), which was only slightly lower than methods involving tasting of food ($r=0.81$). When pictures are used to evaluate preferences, it is highly essential that the pictures resemble the actual food product and the foods picturized must be familiar to the children. In the study described in Paper 2, pictures of yoghurts and smoothies were presented to evaluate children’s visual preferences. The results showed that children ranked the light red smoothie without visible fruit significantly higher than the other smoothies which might be caused by the fact that children are not familiar with smoothies in general. The light red smoothie without visible fruit looked like traditional red lemonade which children are very familiarized with. Lack of frame of references might have induced uncertainty among the children according to ranking of visual preference of smoothies which might have caused them to base their choice on familiarity rather than visual preference. Similar pattern were not observed according to yoghurt since rankings were more equal. This indicates a higher degree of familiarity according to yoghurt.
The use of pictures rather than having the children taste the foods reduces time used for preparation. Therefore, large advantages are gained when using the picture-based conjoint layout to give an initial impression of choice. However, it must be emphasized that the method is not a valid test of the sensory experience for the child.

2.4 Factors influencing sensory evaluation with children

2.4.1 Peer influences

The role of peers has often been noted to have a great impact on children’s food choices and on sensory evaluation (Table 2). Eating is a social behaviour and observing eating behaviours of others, especially peers and parents, influences children’s preferences and behaviour (Birch, 1999). Such modelling of eating behaviours can even result in establishing preferences for foods that are inherently disliked (Patrick and Nicklas, 2005). According to Birch (1980), 3-5 year old children will change their preferences depending on what they see other children eat; e.g. choosing vegetables that they initially did not like after seeing other children eat them. Birch (1980) also emphasized that this behavioural change was not just a result of momentary peer pressure but reflected a true change in preference. The shift in food choice was observed weeks after the experiment in the absence of peers which assumes that the change was relatively long lasting. In this relation sensory evaluation in school environments poses many challenges as friendships and other social structures may influence the results and may not be immediately apparent to the researcher (Hemmingway, 2002). It is crucial that the researcher has a strategy of how to handle the interactions between children, as peer influences in a research setting must be carefully managed. All the studies conducted during this project were carried out in school environments but in settings where it was attempted to minimize the influence of peers. During the trials, all conversations were kept at a minimum. In the preference study (Paper 4-5), children were placed with 2 m. of space
between each child to reduce influence between children. In the evaluation of visual preferences 
(Paper 1-2), children were taken to a separate room when performing the actual product choice. All 
these precautions were taken to minimize peer influence. However, during the exposure study 
(Paper 6), it was impossible to completely avoid peer influence as the exposures took place in the 
class rooms with all children present simultaneously. Especially the oldest children seemed prone to 
influence each other. Therefore, the results presented in Paper 6 may be biased form peer influence.

2.4.2 Time of day

The time of day has shown to be essential when conducting sensory tests with children. Urbick 
(2002) recommends that sensory tests with children are conducted in the morning when children are 
alert, and that sensory tests in the after-school hours are avoided as children are mentally tired. For 
multiple reasons all studies performed in this project were conducted in the morning. First, the 
timetable includes a long break around 10 o’clock, which was very suitable for conduction of 
sensory evaluation without disrupting the teaching. Secondly, all tested products were appropriate 
as in between snacks which are typically consumed at this time. Thirdly, children were expected to 
be alert and not too hungry. Halford et al. (2008) and Capaldi (2001) state that hunger status 
affected preferences. In one study (Paper 2), we asked children about hunger state, and tested the 
influence of ‘time of day’ on children’s visual preferences. We found a strong interaction between 
‘time of day’ and hunger status (p<0.0001) showing that children tested before lunch were more 
hungry than children tested after lunch. The results also showed that ‘time of day’ influenced 
children’s visual preferences. Children tested after lunch preferred more novel (p=0.007) and 
complex foods (p=0.011) compared to children tested before the lunch break (see Table 7, Paper 2). 
Therefore, hunger status is an important factor to bear in mind and to control when modifying 
children’s preferences. The effect of hunger on preferences will be further elaborated in chapter 4.
Another aspect of ‘time of the day’ is the appropriateness of the foods tested. Birch et al. (1984) showed that children aged 3 years old have already learned to categorize foods as “for breakfast” or “for dinner”. In their study, children were asked to consume ‘breakfast foods’ and ‘dinner foods’ at two different times of day. The results showed a significant shift in preference for foods according to ‘time of day’. ‘Breakfast foods’ were more preferred when tasted in the morning compared to the afternoon, and ‘dinner foods’ were more preferred in the afternoon compared to the morning.

The sections described above indicate that many challenges must be faced when conducting sensory evaluation with children.

*In summary, many challenges must be faced when conducting sensory evaluation with children. Children mature along various sensory and cognitive stages when growing up and since children from different sensory and cognitive stages have different abilities, it is important to be aware of the specific stages when performing sensory evaluation with children. Many accepted methods to evaluate children’s preferences and liking exist.*
3 CHANGING CHILDREN’S FOOD PREFERENCES

In order to change children’s food preferences, it is essential to be aware of the factors that influence the development of children’s foods preferences. Some factors are genetically predisposed while others are highly learned through childhood and adolescence. This chapter focuses on the innate and learned preferences of children. I am aware that other factors are highly important in the development of preferences, such as environmental factors, familiarity to the food, the social context in which the food is served, and peer and parental interactions. Some of these will be reviewed in details while others are left out to keep to the primary scope of this thesis.

3.1 Innate preferences

Certain taste preferences are innate, such as liking for sweet and a dislike for bitter and sour tastes (Brug, Tak, te Velde, Bere, and de, I, 2008; Desor, Greene, and Maller, 1975). The genetic disposition toward innate preference for salt has not been clearly established, but liking for a moderate level of salt has been observed among infants at 4 months, which probably is a result of a natural maturation process (Popper and Kroll, 2005). Newborns’ preferences and their reactions towards the five basic tastes (sweet, salt, sour, bitter and umami) have been investigated by analysing their facial expressions while giving them small liquid taste samples (Steiner, 1979, Rosenstein and Oster, 1988).

Newborns rapidly learn to associate flavours of energy-dense foods with the positive post-ingestive consequences (satiety) resulting in increased preferences for high-energy dense foods (Birch and Fisher, 1998). A high preference for sweet taste and fat among children is logical seen from an evolutionary point of view, since the first meal given to newborns, breast milk, is sweet and fat. Additionally, our ancestors were guided by their food preferences in their scavenging for food high
in caloric energy (sweet foods) and by the deterrence for bitter tasting foods as many poisonous plants have a bitter taste (Rozin and Vollmecke, 1986).

It is well known that individuals differ in food preferences and it seems that the genetically coded dislike of bitter tastes results in individual differences in taste perception and preference of bitter tasting foods. The ability to taste bitter thiourea compounds, including 6-n-propylthiouracil (PROP) and phentylthiocarbamid (PTC) proved to be inherited. Approximately, 70% of the U.S Caucasian populations are sensitive to PROP at low concentrations (bitter tasters), while the remaining 30% are not able to taste the bitter taste of PROP (bitter nontasters) (Tepper, 1998). PROP tasters are sensitive to many oral sensations, including bitter and sweet tastes and the sensations of fats and creaminess (Bartoshuk, 1979; Bartoshuk, Rifkin, Marks, and Hooper, 1988; Tepper and Nurse, 1998). Bell and Tepper (2006) studied preschool children and found that bitter nontasters consumed more vegetables than did bitter tasters (p<0.05). As mentioned above children, are predisposed to like, or learn to like, the taste of sweet, salt, and fatty foods and to dislike sour and bitter foods. Nevertheless, some children do acquire a preference for coffee, tea, or beer which emphasizes that it is possible to unlearn the innate dislike of bitterness (Zellner, 1991) and probably also sourness. While the basic tastes may primarily be categorised as pleasant or unpleasant preference for specific and more complex foods is largely learned (Capaldi, 1996; Capaldi and Privitera, 2008).

3.2 Learned preferences

More recent experimental work indicates that food or flavour exposures very early in life are likely to influence preferences later in life. Research has shown that prenatal exposure to a flavour modifies the preference of the same flavour presented a few days after birth (Schaal, Marlier, and Soussignan, 2000) and after 6 months (Mennella, Jagnow, and Beauchamp, 2001). The foods exposed very early in life might have a long-term influence on food preferences. Mennella and
Beauchamp (2002) showed that children aged 4-5 years old had various patterns of liking for different tastes according to the type of formula milks they were fed during infancy. Another study suggested that adults who were fed formula flavoured with vanilla show a preference for food slightly flavoured with vanilla compared to adults who have been breast-fed during infancy (Haller, Rummel, Henneberg, Pollmer, and Koster, 1999). This specifies that the preferences established early in life are tracked into adulthood and it supports the importance of improving children’s unhealthy preferences and dietary habits in a more healthy direction.

The results mentioned above indicate that food preferences are highly stable through lifespan which is further supported by studies by Nicklaus, Boggio, Chabanet, and Issanchou (2004) and Skinner, Carruth, Bounds, and Ziegler (2002). They showed a high stability in food preferences and food variety between the ages of 2-3 and 8 years. When the child is two years old, food refusal, food neophobia, and pickiness start to appear, and it last until the child is approximately 8 years old (see Fig. 11). The age of the children examined in this project ranged from 9-14 years and at this age, children are probably ready to change food preferences.

3.2.1 Effect of hunger

In this PhD study, we found that hunger state highly influenced children’s visual preferences since hungry children preferred less novel and complex foods compared to satiated children (see Table 7, Paper 2). Therefore hunger state should be controlled. The hunger state is also shown to influence food preferences of adults. Booth and Toase (1983) found that adult’s preferences were not only dependent on flavour and energy density but also upon whether the subjects were hungry or satiated. The participants learned to prefer the high energy dense version over the low energy dense version when hungry while the opposite pattern was noted in satiated participants.
In accordance to Maslow’s hierarchy of human needs, the need to cover physiological energy requirements, i.e. overcoming hunger, is among the highest human priorities and the urge to eat and drink when hungry is an inborn trait (Brug et al., 2008). Since eating is the primary way to cover the basic physiological nutrient and calorie requirement, satiety is a strong reinforcement for eating and the reason for energy-dense foods being liked and appreciated. This learned increase in preference transfers to the satiated state and is highly resistant to extinction. Based on this theory, food consumed when hungry will become preferred as a result of the taste of that food being paired with the positive post-ingestive consequences of consumption.

3.2.2 Effect of masking

Another way to change children’s preferences is by using masking techniques. Various sensory properties can be masked, e.g. by using colour masking to mask a change in sensory attributes or chemical composition. Ross et al. (2008) studied the influence of visual masking techniques on the aroma and flavour assessment in two red wines in both trained and consumer sensory panels. The results from the trained panel showed that red illumination in red wines resulted in higher spicy attributes and perceived astringency compared to blue illumination. For the consumer panel, red illumination resulted in wines higher in perceived astringency whereas blue wine glasses resulted in wines higher in perceived flavor liking. In a study investigating the masking effect of fat, Madsen and Ardo (2001) showed that an increase in fat content has a masking effect on bitter taste. In two of our studies (Paper 5-6), masking was an essential part of the experimental design. In Paper 5 one aspect of the study was to elucidate whether or not fat content masked a stepwise increase in fruit content. In this study children’s preference, liking, and wanting for high fat (HF) and low fat (LF) fermented milk product (FMP) (named acidified milk product in Paper 5) prepared with different concentrations of fruit were investigated (Table 3). We found that children liked and wanted the
FMPs with the highest fruit content (15% and 20%) independent of fat content. At low fruit content (5% and 10%), they liked FMP_HF more than FMP_LF, which indicates that the fat content only had a masking effect at low fruit concentrations (see Fig. 2, Paper 5).

The effect of flavour masking was observed in the experiment described in Paper 6. In this experiment, the effect of an increase in designed complexity in FMPs on children’s liking was examined (the design of the products is shown in Table 2, Paper 6). Here, it was observed that in FMP an addition of mango and pear flavour (sample F) masked the addition of fibres and large pieces of mango which was otherwise associated with a decrease in children’s liking (see Fig. 2, Paper 6).

These results indicate that masking techniques may be an efficient method to enhance or suppress changes in sensory attributes or food component.

3.3 Conditioned learning

Learning experiences with foods include flavour-nutrient learning (Johnson, Mcphee, and Birch, 1991), flavour-flavour learning (Havermans and Jansen, 2007), exposure (Birch and Marlin, 1982), parents and peer modelling (Birch, 1980), parental feeding behaviours (Wardle, 1995), and cues about post-ingestive consequences (Birch et al., 1990; Gibson and Wardle, 2003). It has been proved that conditioned flavour preference are extremely resistant to extinction suggesting that conditioned taste preferences are highly stable over a long period (Capaldi, 2001). During the next sections, flavour-nutrient learning and flavour-flavour learning will be reviewed while the effect of exposure will be reviewed in details in chapter 4. Parents and peer modelling and the parental feeding behaviours will not be reviewed to keep the primary scope of this thesis.
3.3.1 Flavour-nutrient learning

Flavour-nutrient learning is a form of Pavlovian conditioning in which an initially disliked/neutral flavour is consistently paired with a high caloric density, e.g. by adding macronutrients to the flavour. Through flavour-nutrient learning, one learns to associate the flavour with the positive post-ingestive effects induced by its nutrient content which leads to increased liking of the flavour. A potential advantage of this method is that very few learning trials are required (less than 10) to establish a relevant shift in preference (Capaldi, 2001). Although flavour-nutrient learning does not require many trials, it does generally require ingestion of a substantial amount of food before the post-ingestive consequences of the nutrients paired with it is experienced. Thus, flavour-nutrient learning may not be the most appropriate method to increase children’s liking of e.g. vegetables, as children show reluctance to consume large amounts of vegetables.

Flavour-nutrient learning has successfully been demonstrated in both adults (Appleton, Gentry, and Shepherd, 2006; Levis, Chambers, and Johnson, 2000; Mela, Trunck, and Aaron, 1993; Stubenitsky, Aaron, Catt, and Mela, 1999) and children (Birch et al., 1990; Jansen and Tenney, 2001; Johnson et al., 1991; Kern, Mcphee, Fisher, Johnson, and Birch, 1993). Levis et al. (2000) measured liking for specific flavours paired with cream cheese with a varying content of fat in adults. They found increased liking for flavours paired with high fat cream cheese and decreased liking for flavours paired with low fat cream cheese. Oppositely, Stubenitsky et al. (1999) and Mela et al. (1993) did not find any changes in liking following flavour-nutrient learning in adults. Birch et al. (1990) investigated the effect of flavour-nutrient learning in children and proved that children learned to prefer flavours paired with high-caloric drinks compared to low-calorie drinks. Similar results were achieved in a study by Johnson et al. (1991) who showed that children increased their preference for a high density paired flavour, whereas no changes in preference were noted for the low-density paired flavour.
The results in *Paper 5* showed that the addition of 15% and 20% fruit to both FMP\_LF and FMP\_HF resulted in an increase in mean rating scores of both liking and wanting (see Fig. 2, *Paper 5*). One might argue that the observed increase in liking and wanting might be a result of flavour-nutrient learning as the content of calories (kilo Joule (kJ) in the FMPs increased with increasing fruit concentration (Table 3).

<table>
<thead>
<tr>
<th>Fruit %</th>
<th>kJ total in FMP_LF</th>
<th>kJ total in FMP_HF</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>799</td>
<td>889</td>
</tr>
<tr>
<td>10%</td>
<td>816</td>
<td>906</td>
</tr>
<tr>
<td>15%</td>
<td>850</td>
<td>940</td>
</tr>
<tr>
<td>20%</td>
<td>850*</td>
<td>940</td>
</tr>
</tbody>
</table>

**Table 3** Composition of fruit and calories (kJ) in the four fermented milk products.

* When the fruit content is increased from 15% to 20%, the starch content was reduced from 3% to 2% which results in an even calorie content (kJ) between FMP\_15% and FMP\_20%. The reason for not adding the same amount of starch to all FMP samples was caused by the fact that the consistency of the marmalades would have changed.

We do not believe that the increase in liking and wanting of the FMPs is a consequence of flavour-nutrient learning as the increase in kJ between FMP\_LF (5% fruit) and FMP\_LF (10% fruit) was relatively small (from 799 kJ to 816 kJ). Moreover, the children only tasted each of the four FMP samples once and in quite small amounts (100 ml) (*Paper 5*).

A modification of calorie content was also seen in *Paper 6*. Here children’s liking for six FMPs with a step-by-step change in designed complexity was investigated during exposure. The modification in designed complexity and calorie content of the six (A-F) FMPs is shown in Table 4.

<table>
<thead>
<tr>
<th>Code</th>
<th>Products</th>
<th>kJ total in FMP’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FMP</td>
<td>1187.6</td>
</tr>
<tr>
<td>B</td>
<td>FMP+small pieces of pear</td>
<td>984.9</td>
</tr>
<tr>
<td>C</td>
<td>FMP+small pieces of pear+mango puree</td>
<td>937.3</td>
</tr>
<tr>
<td>D</td>
<td>FMP+small pieces of pear+mango puree+fibres</td>
<td>983.2</td>
</tr>
<tr>
<td>E</td>
<td>FMP+small pieces of pear+mango puree+fibres+large pieces of mango</td>
<td>889.5</td>
</tr>
<tr>
<td>F</td>
<td>FMP+small pieces of pear+mango puree+fibres+large pieces of mango+flavours</td>
<td>894.0</td>
</tr>
</tbody>
</table>

**Table 4** Description of the six FMPs varying in level of designed complexity. The FMP used in sample A-F was a basic FMP added banana and pear puree.
The children were divided into three exposure groups and exposed to three different FMPs (sample A, D, and F, respectively). Children exposed to sample F increased liking for sample F even though this FMP contains low calorie content compared to the other FMP samples (except for sample E). The other groups, which were exposed to the more calorie dense sample A and D, respectively, did not show an increase in liking during exposure (see Fig. 2, Paper 6). Therefore, the increase in liking observed in the group exposed to sample F is not a result of flavour nutrient learning but more likely a reduction of novelty, appreciation of increased creaminess and sweetness, and increased level of designed complexity (see Fig. 5 and 6, Paper 6). Often, studies lack the control necessary to reliably demonstrate an effect of conditioning as increases in liking also may develop as a consequence of increased exposure (Pliner, 1982; Wardle, Herrera, Cooke, and Gibson, 2003).

When using flavour-nutrient learning as a tool to increase liking of more healthy and less liked food products, it is important to be aware of the delay of post-ingestive effects after consumption. In many cultures, it is a tradition to serve a desert at the end of a meal. Though, when a desert is served directly after a meal there is a large opportunity of the desert being more closely associated with the post-ingestive consequences of the meal more than being associated with the flavour or food of the meal (Capaldi, 2001). This phenomenon is called the ‘dessert effect’. To obtain an increase in preference, the food or flavour should be mixed with an already preferred food, e.g. vegetables should be served with high energy dense meat or fruit and vegetables should be served as a dessert. This method is not commonly known to increase children’s preferences. Often children are promised a preferred food after they have consumed the less preferred food. Consequently, children’s preferences for an already disliked food are decreased. Numerous studies indicate that rewarding children for eating disliked or low preferred foods does not lead to increased liking (Birch, 1999).
3.3.2 Flavour-flavour learning

Another flavour conditioning procedure called flavour-flavour learning have been used to change children’s preferences (Brunstrom and Fletcher, 2008; Havermans and Jansen, 2007; Capaldi, 2001). The principle behind flavour-flavour learning is that one learns to associate a disliked/neutral flavour with a highly preferred flavour/taste (e.g. sweetness). This procedure may account for how some initially disliked foods and beverages, such as coffee, come to be liked. Most individuals initially drink coffee with sugar and cream and afterwards they come to like the bitter taste of black coffee (Capaldi, 2001). The effect of flavour-flavour learning has predominantly been investigated in animals but there is some empirical evidence that likes and dislikes of specific flavours can be conditioned through flavour-flavour learning in humans too (Baeyens, Crombez, Hendrickx, and Eelen, 1995; Havermans and Jansen, 2007; Zellner, Rozin, Aron, and Kulish, 1983; Capaldi and Privitera, 2008). Zellner et al. (1983) observed an increase in preference of a specific tea flavour after the tea had been presented several times in combination with the sweet taste of sucrose.

Results from Havermans and Jansen (2007) showed positive effects of flavour-flavour learning on children’s liking of an initially disliked vegetable. They served various vegetable flavours diluted with water. To one taste 20 g dextrose was added whereas the other taste remained unsweetened. During pre-test and post-test, children were asked to rank the vegetable flavours according to preference. The results showed that flavour-flavour learning effectively produced an increase in children’s preference for specific vegetable tastes also after flavour pairing. One may argue that sweetening foods with sugar to increase food preferences is against the ultimate goal of reducing propensity for obesity in children. But as children are born with an innate preference for sweetness, it is obvious to take advantage of this taste component to increase liking for foods that are healthy. Flavour-flavour learning has also proven to be effective in producing dislikes. Capaldi (2001) demonstrated that by mixing a flavour with quinine a later dislike for that flavour was established.
In summary, children’s innate preferences can be changed during learning processes and conditioned learning. Both controlling hunger state and various masking techniques are shown to be essential tools to change and improve children’s food preferences.
4 NEOPHOBIA AND MERE EXPOSURE

To persuade a child to adopt healthier food choices, intervention studies that consider the complex interplay between the innate and learned preferences (Desor and Beauchamp, 1987), cognitive ability (Michela and Contento, 1986), parental dietary habits (Fisher, Mitchell, Smiciklas-Wright, and Birch, 2002), and peer influence (Birch, 1980) are required. However, the strongest psychological barriers to increase a child’s dietary variety and improve dietary habits are food neophobia (Birch et al., 1998; Falciglia, Couch, Gribble, Pabst, and Frank, 2000) and ‘picky/fussy’ eating (Galloway, Lee, and Birch, 2003).

4.1 Neophobia

Food neophobia is defined as the rejection of foods that are novel or unknown to the child while ‘picky/fussy’ eating is the rejection of a large proportion of familiar (as well as novel) foods. Both conditions results in a habitual diet characterized by an intake of a particular low variety of foods (Dovey, Staples, Gibson, and Halford, 2008). The term ‘neophobia’ is derived from Rozin’s ‘omnivore’s dilemma’ (Rozin and Vollmecke, 1986) which is a process described as an evolutionarily survival mechanism in children to avoid consuming toxic chemicals once they are mobile enough to consider, pick up, and consume ‘objects’ found when outside parental vision (Birch et al. 1998). Food neophobia aids this avoidance mechanism as the children naturally reject foods that they have no experience with (Zajone, 1968). Consequently, neophobia is considered to serve a protective function. Foods that do not ‘look right’ to the child will initially be rejected based on vision alone. This neophobic predisposition to avoid new foods may seem maladaptive for species that need to consume a varied diet to obtain adequate nutrition and might also explain why neophobia changes during childhood.
Age and gender differences as well as individual differences are present in the strength of neophobic response and food neophobia may be genetically inherited as familial similarities in food neophobia are observed (Hursti and Sjöden, 1997). In this study, they reported moderate relationships between parents’ and children’s food neophobia (Hursti and Sjöden, 1997) and Koivisto and Sjöden (1996) showed that males had greater neophobic behaviour than females, both among children and adults. These authors also confirmed that during childhood, the neophobic response to new foods decreased with age which indicates that the strength of the neophobic response changes during development. Birch et al. (1998) have shown that among infants who were just beginning the transition to solid foods, the neophobic response appears to be minimal. Here, mothers introduced 4-6 months infants to new fruits or vegetables by feeding one new food to the infant over series of 10 lunches. The results indicated that only one feeding with a new food was sufficient to increase an infant’s intake of that food significantly from a mean of 30 g at the first feeding to a mean of 60 g at the second feeding. In addition, this reduction in neophobia appeared to generalize to similar foods, so if an infant has experience with one vegetable, other vegetables are more frequently eaten. Unfortunately, the result obtained for 4-6 months infants is in contrast with the pattern of findings obtained when toddlers, children, and adults are repeatedly exposed to new foods (Cooke, Wardle, and Gibson, 2003). Beyond infancy, food neophobia may be more persistent; in research with 2-5 year old children, an average of 5-10 exposures to a new food were required to produce significant increases in children’s preferences (Birch et al. 1982). Pliner and colleagues explored age differences in food neophobia among older children and adults, comparing 3-8 year old with 10-20 year old children (Pelchat and Pliner, 1995; Pliner, 1994; Pliner and Loewen, 1997). Similar results were also seen in study by Koivisto and Sjöden (1996). These findings suggest that during development the relationship between age and the neophobic response
may be curvilinear. Food neophobia is minimal during infancy, increases through early childhood, and declines from childhood to adulthood. This curvilinear relationship is illustrated in Fig. 11.

Fig. 11 A lifespan model for levels of food neophobia in humans suggested by Dovey et al. (2008).

As children age, their food experiences increase and they develop different likes and dislikes which results in a reduction in food neophobia (Cooke and Wardle, 2005). With experience via mere exposure, learning can transform the initial neophobic rejection of a novel food into a preference (Zajonc, 1968).

4.2 Mere exposure

Zajonc (1968) was the first to identify the effect of ‘mere exposure’ across various scientific areas and he demonstrated that exposure to a stimulus can enhance liking and acceptance. He defined the ‘mere exposure’ effect as: “Exposure of the individual to a stimulus is a sufficient condition for the enhancement of his attitude toward it. By ‘mere exposure’ is meant a condition which just makes the given stimulus accessible to the individual’s perception” (Zajonc, 1968). Additionally, he suggested that an initially novel stimulus elicits negative effects simply because of novelty but that
exposure is sufficient to reduce the degree of novelty resulting in an increased positive attitudinal responding.

4.2.1 Effect of novelty and familiarity

Experience and increased familiarity (i.e. eating small amounts of the food and suffering no ill effects) can transform the initial neophobic response into liking and acceptance via ‘learned safety’ (Kalat and Rozin, 1973). Experimental studies with adults (Essed, van Staveren, Kok, Ormel, Zeinstra, and de Graaf, 2006; Luckow, Sheehan, Fitzgerald, and Delahunty, 2006; Pliner, 1982) and children (Birch and Marlin, 1982; Birch, Mcphee, Shoba, Pirok, and Steinberg, 1987; Liem and de Graaf, 2004; Sullivan and Birch, 1994; Wardle, Cooke, Gibson, Sapochnik, Sheiham, and Lawson, 2003; Wardle et al., 2003) have provided strong support for the efficacy of mere exposure and demonstrated that tasting a food or a drink increases familiarity and liking of the given food/drink. In a study by Pliner (1982), adults were exposed to unfamiliar tropical fruit juices 5, 10, 15 or 20 times. The results showed that a high exposure frequency implied high rating scores, which suggests that increased familiarity increased liking in adults. Essed et al. (2006) investigated the effect of mere exposure to fruit drinks on intake, pleasantness, and boredom in young and elderly adults. They were not capable to prove a positive effect of mere exposure to fruit drink on liking. However, the results showed that after mere exposure intake (p<0.01) and pleasantness (p<0.01) decreased significantly while boredom increased (p<0.001) in young adults whereas intake increased (p=0.03) and pleasantness (p=0.34) and boredom (p=0.40) remained stable in elderly adults.

In a study of children’s food preferences, Birch (1979) supported that familiarity was a key factor in explaining children’s liking. The importance of familiarity and mere exposure on children’s liking was demonstrated by Birch and Marlin (1982). Two year old children were exposed to unfamiliar
foods (fruit and cheese) through a period of several weeks and the results showed that mere exposure increased liking. Children who were given frequent opportunity to taste the food through the exposure period grew to like it, in contrast to those children who were offered the same food less frequently. Loewen and Pliner (1999) exposed 7-9 year old and 10-12 year old children to good-tasting familiar food, good-tasting novel foods and bad-tasting novel foods. After rating their willingness to taste the various foods, the results demonstrated that exposure to good-tasting novel foods increased willingness to taste novel foods in general compared to the good-tasting familiar control. Similar results were achieved in another study by Pliner and Stallberg-White (2000). These results emphasize that a certain degree of novelty must be present to increase liking. If novelty of the exposed food is too low, mere exposure probably results in boredom. The boredom effect has frequently been shown with stable foods like bread, butter, and milk (Siegel and Pilgrim, 1958).

4.2.2 Factors influencing the effect of exposure

In the present project, one of our sub-aims was to investigate if children’s preferences could be changed in a healthier direction e.g., by mere exposure and we performed a study on the effect of mere exposure on children’s liking (unpublished results). One of the aims in this study was to explore the effect of mere exposure to apple juices varying in sourness and colour on children’s liking. The children were 9-11 years old. In this study children were exposed to a new apple juice which was perceived as more sour than a normal apple juice since it was produced on Danish apples. All apple juice samples were made on an apple juice base (sample 1). Sample 2 was added malic acid, sample 3 was added choke berry concentrate and sample 4 was added both malic acid and choke berry concentrate (Table 5). The children were divided into four exposure groups (Gr.1-4) and one control group and each day through the exposure period the four exposure groups were exposed to apple juices varying in colour and sourness (see Table 5).
Pre-, midway and post-exposure children were asked to rate liking of the apple juices. Each exposure day children’s intake of apple juice was registered. The exposure period lasted for 15 school days and the design of the study is shown in Fig. 12.

The statistical analysis of the results showed that mere exposure had no effect on children’s liking in any of the exposure groups since liking remained stable throughout the exposure period (see Fig. 13). However, an effect of mere exposure was observed according to intake. During the exposure period intake of one of the yellow apple juices (Gr.1) increased significantly while intake of one of the red apple juices significantly decreased (Gr. 4) (Fig. 13). This difference in liking and intake is noteworthy.
Fig. 13 shows the development of liking and intake through the exposure period (unpublished results).

The significantly lower intake observed in Gr. 1 pre-exposure compared to the other exposure groups may be caused by the fact that the apple juice, which was a normal yellow apple juice, was too familiar. The other apple juices all had some degree of novelty causing the higher intake. However, during mere exposure novelty decreases and results in boredom and decreased intake. One explanation for the non-significant effect of mere exposure on liking ratings for all exposure groups may be that preferences for sour taste are more stable during childhood compared to preferences for sweet taste. Previous studies of children’s preference for sour taste have concluded that preferences for sour taste can be changed by long-term exposure (approximately 8 months) during infancy (Liem and Menella, 2002; Mennella and Beauchamp, 2002). The exposure period to the apple juices in the present study was only 15 days. Liem and de Graff (2004) exposed children to a sweet and a sour drink during eight days. They found that mere exposure to a sweet drink increased children’s liking whereas mere exposure to a sour drink remained children’s liking stable. Both drinks were initially liked equally well. They concluded that sweet preferences of children can be modified by only few mere exposures during childhood whereas sour taste preferences appear to be more stable. More studies are needed to elucidate the development of children’s sour preferences.
and to explore the consequence of an alternative learning process for sour food products compared to sweet food products.

Another explanation may be that liking for stable products as apple juice are found to be highly stable or even decreased through mere exposure (Siegel and Pilgrim, 1958).

Another mere exposure study was conducted in this PhD project and here a significant increase in liking was observed during the exposure period (Paper 6). Children were divided into three exposure groups (Gr.1-3) and one control group. The exposure groups were exposed to fermented milk products (FMP) varying in designed complexity (low, medium and high) during ten days whereas the control group received no exposures (see Table 3, Paper 6). Children were asked to rate liking for six FMPs varying in designed complexity pre- and post-exposure. The results showed that the group exposed to the FMP with highest level of complexity (Gr. 3) increased liking for the most complex FMP (sample F) while they decreased liking for the least complex FMPs (sample A-C). No changes in liking were observed in the other exposure groups (Gr.1 and Gr. 2) except for a decrease in liking for sample D in Gr. 1 and a decrease in liking for sample B in Gr. 2 (see Fig. 2, Paper 6). This result clearly proves that mere exposure significantly affects liking. However, the differences in changes in liking observed in this exposure study may also be ascribed to differences in level of designed complexity. This concept will be further discussed in chapter 5.

4.2.3 Frequency and number of exposures

Research does not show consistency in frequency and number of exposures important for an increase in liking and these issues have not received much attention in the literature. However, timing and frequency of exposure are essential to the result and should be carefully considered. When determining frequency of exposure, the natural consumption pattern of the specific food or beverage should be taken into account to avoid product boredom (Mennella, Griffin, and
Beauchamp, 2004). Some may argue that exposing children on a daily basis, as we did in the exposure studies described above, was too frequent to achieve an increase in liking. Exposures one or two times a week may be sufficient to increase liking and to avoid product boredom. However, the study described in Paper 6 showed that even though children were exposed to the FMPs each day, an increase in liking occurred. Future research is needed to clarify this issue.

Also the number of exposures seems to be essential to achieve an increase in liking. Birch and colleagues found that five to ten exposures were required to increase 2 year old children’s liking for novel foods (Birch and Marlin, 1982) whereas eight to fifteen exposures were required to enhance 3-4 year old children’s preferences (Birch et al. 1987). Liem and de Graff (2004) showed that eight exposures were enough to increase 8-11 year-old children’s preferences whereas results from a study by Loewen and Pliner (1999) showed that twenty exposures were required in 7-12 year old children to increase liking. These results indicate that the sufficient numbers of exposures varies between age groups of children and that more exposures are required with increasing age.

In summary, mere exposure helps reducing food neophobia by increasing familiarity and thereby liking. When performing mere exposure one should be aware of the product exposed as preference for some products are easily changed while liking for other products are highly stable.
5 ROLE OF PERCEIVED COMPLEXITY

In chapter 4, a change in liking was ascribed to depend on food neophobia, product novelty and mere exposure. Besides these factors, a change in liking during exposure can be affected by changing the level of perceived complexity of the stimuli (Berlyne, 1970; Dember and Earl, 1957).

5.1 Definition of complexity

The definition of the attribute ‘complexity’ has been a subject of controversy among psychologists through decades. It is generally recognized that two stimuli of equal familiarity may not be equally attractive since they differ in degree of perceived complexity. Dember and Earl (1957) stated that a highly complex stimulus is one, which the individual can do more with, and thus “affords more potential opportunities for responding” than a less complex stimulus. When examining the effect of perceived complexity on liking and acceptance, it is either defined a priory on the basis of theoretical considerations or it is measured by using rating scales or paired comparison. During this project the effect of the attribute ‘complexity’ on visual preferences and liking has been explored and to get closer to a definition of the term a descriptive panel were asked to evaluate pictures of fruit and vegetable mixes varying in designed complexity (Fig. 3, Paper 3). The descriptive panel agreed on a definition of the term ‘complexity’ by saying “the more energy you spend to get an overview of the pictures the more complex it is” which is in line with the definition given by Dember and Earl (1957). In addition, the perceived complexity evaluated by the descriptive panel was highly correlated to designed complexity (Fig. 4, Paper 3). Perceived complexity is one of the collative properties influencing an individual’s optimal arousal potential. The arousal potential has been used to describe various dimensions of physiological changes (Berlyne 1967) and it is a determinant for the degree of liking of a stimulus (Berlyne, 1970). Berlyne (1967) described a set of properties which evoke the arousal potential. These
properties are divided into three groups: psychophysical properties such as stimulus intensity and stimulus quality, ecological properties such as internal changes that accompany hunger, thirst, sexual appetite etc., and collative properties such as novelty, variety, surprisingness, perceived complexity, incongruity, and ambiguity. The basic assumption is that especially the collative properties affect the level of arousal potential (Berlyne, 1963). In food science of today, much research is focused on how novelty, intensity and perceived complexity of foods affect the arousal potential and thereby liking and acceptance. In the current project, we investigated how a change in novelty and designed complexity affected children’s liking and acceptance of foods with a more healthy profile.

5.2 Effect of stimulus complexity on the arousal potential

Berlyne (1967) hypothesized that an intermediate level of arousal is optimal for making changes and increase learning and he proposed an inverted U-form relationship between arousal potential and hedonic values of stimuli’s (Fig. 14) (Berlyne, 1970). Fig. 14 indicates that there is an optimal arousal potential level which highly depends on the level of novelty and perceived complexity.

![Fig. 14 The Wundt curve (Berlyne, 1970). An illustration of how novelty and perceived complexity affects hedonic value as a function of arousal potential of a stimulus.](image)
The figure distinguishes between situations in which the level of stimulation is below and above the individual’s optimal arousal potential. When the actual level of stimulation is below the optimum (A), an individual will seek stimulation, by adding variety or novelty. In contrast, when the actual level is above the optimum (C), the individual avoids stimulation by avoiding variety or novelty. A stimulus that is high in both novelty and perceived complexity will be high in arousal potential (region C). As the stimuli becomes more familiar, the point representing the arousal potential will shift towards region B accompanied by an increase in liking and acceptance (Berlyne, 1970). The optimal arousal potential varies among individuals and it is momentary in time for each specific stimuli. What is too simple for an adult may be just right about for a child and what is too complex for the novice may be ideal for the sophisticate.

The optimal arousal potential highly depends on learning and experience, and it is usually assumed to change from less to more complex stimuli (Dember and Earl, 1957). Dember and Earl (1957) explained this learning-effect by assuming that experience to a somewhat more than optimally arousing stimulus (a pacer) (B) will increase an individual’s optimal arousal potential (Fig. 15-left side). This leads to a diminished arousal potential of the stimulus and an improved liking of the stimulus. Fig. 15 also illustrates that experience to a stimulus with an arousal potential (C) being lower than optimal does not affect the optimal arousal potential and it leads to a decline in liking and acceptance.

5.3 Experience reduces perceived complexity

Walker (1980) extended the theory of Dember and Earl (1957) to include the effect of experience on perceived complexity and liking which can be seen in Fig. 15-right side. This part of the figure shows that perceived complexity of a stimulus can be reduced by mere exposure with that specific stimulus. During mere exposure with a stimulus that is above the optimal arousal potential, liking
will initially increase, whereas mere exposure to a stimulus below the optimal arousal potential will
decrease in liking and result in product boredom.

Fig. 15 also illustrates that stimuli with a lower than optimal liking and high perceived complexity (B) would sustain liking for a longer period than stimuli with high initial liking and low degree of
perceived complexity.

![Diagram](image)

**Fig. 15** The relationship between liking and arousal potential (**left side**) and the effect of experience on liking and
arousal potential (**right side**). **Left side:** the solid line represents initial levels, whereas the broken line represents the
changes that occur with exposure to a pacer. A is the originally optimal arousal level of complexity, B is a somewhat
more complex stimulus (the pacer), and C is a less complex stimulus. In this side of the figure, the theories from
Dember and Earl (1957) and Berlyne (1967) are combined (Levy et al., 2006). **Right side:** Changes in complexity and
liking during exposure. The solid line represents exposure to stimulus B, and the broken line represents exposure to
stimulus A. In the figure, the theories from Dember and Earl (1957), Berlyne (1967) and Walker (1980) are combined,
inclusive the theory proposed by Zajonc (1968).

Since the motivational theories of Berlyne (1960), Dember and Earl (1957) and Walker (1980) were
presented experiments within as different scientific disciplines as music, semantics, visual stimuli,
fragrances and food science have been conducted to confirm the role of the optimal arousal
potential and perceived complexity as essential factors in the development of liking. In 2006, Levy et al. performed a very fundamental study within food science. Here, they investigated various collative properties and liking in adults for seven orange drinks varying in designed complexity by adding small quantities of flavours. They confirmed that mere exposure to an orange drink with a slightly higher degree of complexity than the individual’s optimal arousal potential increased liking. This effect was not achieved for individuals who were only exposed to simple orange drinks. Another fundamental study was performed by Weijzen, Zandstra, Alfieri, and de Graaf (2008) who studied adults’ acceptance of crackers and soups with a varying level of designed complexity during mere exposure. After mere exposure, it was observed that acceptance of stimuli with optimal arousal potential was more resistant to a decline than acceptance of stimuli with lower arousal potentials. Other authors demonstrated the fragility of the motivational theories which may easily be affected by other differences between the stimuli than perceived complexity alone, such as differences in caloric content (Zandstra, de Graaf, and van Trijp, 2000) or sweetness of the food products (Sulmont-Rosse, Chabanet, Issanchou, and Koster, 2008). Porcherot and Issanchou (1998), however, could not ascertain the relation between perceived complexity and liking over mere exposure.

Experiments focusing on the effect of perceived complexity on children’s liking are sparse. One explanation is that the evaluation of the relationship between perceived complexity and liking is complicated as children have difficulties in understanding the term ‘complexity’. Reverdy, Schlich, Koster, Ginon, and Lange (2010) investigated liking of 8-10 year old children for stimuli differing in arousal potential during a sensory education program. The children evaluated liking for five stimuli varying in designed complexity in each of three product categories (mashed potatoes, fruit yoghurts, and compotes). The results indicated that few exposures of the more complex products
were sufficient to improve the liking for complex foods and at the same time reduce liking for simpler variants.

In the current project, the motivational theories and how they affected children’s liking were investigated. The study described in Paper 6 illustrates how mere exposure to three FMPs (sample A, D, and F) with a design varying in intensity, novelty and complexity affected children’s liking of six FMPs (see Table 1 and 2, Paper 6). Children were divided into three experimental groups (Gr.1-3) and one control group. The experimental groups were exposed to FMPs varying in designed complexity by either being low (sample A), medium (sample D) or high (sample F) in designed complexity (see Table 3, Paper 6). Based on the motivational theories, we expected a decrease in liking for the least complex FMP (sample A) in all exposure groups during mere exposure as sample A was designed to be below children’s optimal arousal potential. Further, it was expected that Gr. 3 which was exposed to the most complex FMP (sample F) would increase liking for the most complex FMP (sample F) and decrease liking for the least complex FMP (sample A) during mere exposure. The results showed that after ten exposures, a significant increase in liking was only observed for Gr. 3 which was exposed to the most complex FMP (sample F). Additionally, Gr. 3 showed a decline in liking for the least complex FMPs (sample A). These results are very well in line with the theories of Berlyne (1967), Dember and Earl (1957), and Walker (1980). However, as mentioned above the motivational theories are fragile and they may easily be affected by other factors than perceived complexity. Another explanation for the increase in liking in Gr. 3 for sample F could simply be a reduction of novelty of sample F after mere exposure. Moreover, a decreased appreciation of the thinner and less creamy samples after exposure of the thicker and creamier samples paired with a positive flavor may also be a reason for the increase in liking for sample F. An unexpected result was observed for Gr.1, which was exposed to the least complex FMP (sample A), as a tendency to a small increase in liking for sample A was registered whereas a tendency to a
decrease in liking for the more complex FMPs was observed in this exposure group. The absence of a decrease in liking for sample A in Gr. 1 may be interpreted to be caused by the fact that even the simplest FMP was perceived as more complex than their initial optimum arousal potential. Another possible explanation could be a mere exposure effect.

Due to the difficulty in defining some of the collative attributes in children, we did not ask the children to evaluate the terms complexity, intensity, and novelty and we decided the designed complexity a priori. In a study by Reverdy et al. (2010), children were asked to evaluate familiarity, intensity, and complexity by paired comparison to characterize the arousal potential of the stimuli. They asked three questions: 1) “Which sample do you know best?” (Familiarity), “Which sample is the most intense?” (Overall intensity), “Which sample contains the highest number of tastes?” (Complexity). Questions like these might have provided us with additional insight into children’s perception of the FMPs.

This study is, to the author’s knowledge, the first study conducted with children studying the effect of novelty, intensity and designed complexity on liking.

5.4 Designed complexity vs. perceived complexity

In the studies based on the picture-based conjoint layout described in Paper 2 and 3, it was investigated how designed complexity and novelty affect children’s visual preferences for yoghurts, smoothies (Paper 2) and fruit and vegetable mixes (Paper 3). Further, in one of the studies the correlation between designed complexity and perceived complexity was investigated by using a descriptive panel to evaluate the perceived complexity of the pictures (Paper 3). As mentioned above children may have difficulties in evaluating the attribute complexity and a measure for perceived complexity was thus obtained through a descriptive panel. This measurement was found to be the best alternative and an approximation towards adults and adolescents’ perception of
complexity. The results showed a very high correlation (r=0.86) between designed and perceived complexity (Fig 4, Paper 3) which specifies that designed complexity is a reliable measure for perceived complexity according to pictures of fruit and vegetable mixes according to adults. Additionally, it indicates that we all, in this case the researcher and the panel, have some sort of common understanding of what is perceived more or less complex. This high correlation between designed and perceived complexity, made it relevant to investigate the effect of designed complexity on children’s visual preferences. In Paper 2 and 3, children made incomplete rankings of pictures of yoghurt and smoothies (Paper 2) and fruit and vegetable mixes (Paper 3) varying in designed complexity and other collative properties. In both studies designed complexity and colour was seen to affect visual preferences (see Fig. 2 and Table 5, Paper 2 and Table 2abc, Paper 3). In Paper 2 children in general preferred the dark red yoghurt (novel) over the light red yoghurt (familiar) indicating that novelty has a large influence on their visual preferences. Moreover, addition of “visual fruit pieces” influenced children’s visual preferences as they preferred the yoghurt without fruit pieces (least complex) significantly over the yoghurt with visible fruit pieces (most complex). These results indicate that children visually prefer food products with a high degree of novelty and a low degree of designed complexity. These results may be influenced by the fact that children in general do not like inhomogeneous yoghurt. However, the influence of liking was not investigated in this study. In Paper 3, however, the influence of children’s liking on visual preference was evaluated and the results clearly showed that for both adults and adolescents liking of the products influences visual preferences for the mixes (Table 3, Paper 3).

In contrast, results from examining children’s taste preferences for FMPs (named AMP in Paper 5) with a step-by-step change in fruit concentration showed that an increase in visual fruit pieces increased children liking and wanting (see Table 4 and Fig. 2, Paper 5). Therefore, it must be emphasized that an increase in children’s liking for foods with a higher degree of complexity seems
to require actual taste evaluations and mere exposure to decrease the effect of novelty and food neophobia.

Although the learning mechanisms described in chapter 4-6 are indeed very diverse in nature, they all have in common that they are forms of implicit non-intentional learning strategies and that they result in implicit and unconscious food preferences and habits. This might explain why such habits are highly resistant to change as interventions often are based on conscious and rational argumentation.

*In summary, the degree of novelty and perceived complexity of foods influences the optimal arousal potential. Learning and experience to a somewhat more than optimally arousing stimulus was shown to increase children’s optimal arousal potential and improve liking of complex foods. However, it is important to be aware that the motivational theories are fragile and other factors than perceived complexity may affect visual preferences and liking. Future research in how perceived complexity is evaluated in children is needed.*
6 CHILDREN AS TEST PERSONS

The research process is bound by constraints and several decisions have to be made during the design and performance of a study. Some of the decisions made according to e.g. children’s cognitive development and which sensory methodologies to use have been elucidated and discussed in chapter 2. A few other issues related to children as target population will be highlighted in this final chapter. These issues and decisions should be taken into account when interpreting the results in this thesis.

6.1 Recruitment

The children who participated in the studies described in this thesis were recruited via primary schools. The use of schools as test settings was chosen to get honest answers as it is important that children feel comfortable when they participate in a test. However, recruitment via schools can be a source of selection bias as only schools that are motivated and interested in healthy eating among children will participate. There are three other potential sources of selection bias. First, parents that are highly involved with and interested in healthy eating are likely to give permission for their children to participate. However, we did not experience any parents to be reluctant against their children participating in the experiments. Two mothers called us and kindly asked us to be discrete about the body weights of their children. Most parents were very interested in how to change their children’s dietary habits in a more healthy direction. Secondly, children from non-Danish-speaking parents may not have been included in the experiments since all information we send out was in Danish. Thirdly, if parents forgot to sign an informed consent for their child, children were excluded from participation even though the child was willing to participate. It is unlikely that these selection biases have influenced our results as we focused on sensory, biological and psychological processes that are presumably not influenced by the involvement of parents, their forgetfulness or
their habitual language. However, children’s dietary habits will be influenced by differences in parent’s habitual diet. Parents that are less interested in healthy foods may have other dietary habits or different perceptions about healthy foods which may influence children’s behavioral answers. (Paper 1-2, 4).

6.2 Number of participants

In all the experiments conducted in this project, a high rate of participation was achieved. Paper 1: 82% of children; Paper 2: 98% and 92% of the children; Paper 4: 82% of the children, Paper 5: 86% of the children; Paper 6: 90%. In Paper 3 dropout was not registered. Most of the drop outs were caused by illness or vacations which are considered as random drop outs and will not have distorted our results. Few children refused weight and height measurements because of embarrassment of being overweight which may have influenced results.

6.3 Evaluation of childhood BMI

The future perspective of this thesis is to develop a strategy to change children’s preferences in a healthier direction and thereby decrease the development in childhood obesity. Nutritional status in childhood and adolescents is of particular concern as obesity at this period of life is associated with adult mortality and morbidity (Must and Strauss, 1999). Calculation of BMI can be used to classify people as normal weight (BMI: 18.5-24.99 kg/m2), overweight (BMI≥25kg/m2) or obese (BMI≥30 kg/m2) (WHO). However, using the normal BMI index for the estimation of childhood obesity is problematic as BMI changes with age, gender and puberty. Therefore BMI z-scores adjusted for age and gender have been developed (Cole, Bellizzi, Flegal, and Dietz, 2000). The reference percentiles are based on children in an international reference population meaning that they can be used internationally to estimate and compare BMI z-scores. Fig. 16 shows BMI values adjusted for age
and gender based on a British reference population. The figure also shows BMI values of 25 kg/m² (overweight) and 30 kg/m² (obesity) at the age 18.

Fig. 16 International reference percentiles used for estimation of overweight and obesity in British children and adolescents. BMI values of 25 kg/m² (overweight) and 30 kg/m² (obesity) at the age of 18 are shown.

These BMI z-scores were used to calculate BMI values for children in this project (Paper1-2, 4-5).
7 CONCLUSIONS AND FUTURE PERSPECTIVES

In the introduction, Fig. 2 provides an overview of the empirical design of the present project and suggests how the specific sub-aims would be achieved. Fig. 17 briefly sketches the significant conclusions from the various empirical parts of the PhD project.

**Evaluation of visual preferences**  
*Paper 1-3*

The picture-based conjoint layout of various foods provided reproducible and valid information about children’s visual preferences and actual food choice.

Results from the three papers show that food appearance factors such as colour, visible fruit, turbidity, novelty and designed complexity play an essential role to children’s visual preferences.

Additionally, variables such as grade, affiliation, hunger state, gender and ethnicity were found to be significant drivers for visual preferences and food choice.

**Evaluation of taste preferences**  
*Paper 4-6*

Regarding beverages, children preferred the less sour ones. Yet, around 15 g of dry matter: apple juice, preferences were stabilized which indicates that an upper limit in children’s sweetness preferences exists. In addition, a minor segment of children preferring the most sour apple juice was found.

Children liked and wanted FMPs with very high fruit content compared to the ones with low fruit content. At high fruit contents, fat content did not influence liking while high fat FMPs were most liked at low fruit content.

Results showed that various segments of children had different food preferences, liking and wanting.

---

**Fig. 17** Conclusions of the empiric studies conducted in the present PhD project.

The overall conclusion based on Fig. 17. is that we demonstrate that **modelling of children’s food preferences and foods simultaneously enables a change of children’s perception, preference, liking and wanting for healthier food products.**
To be more specific, we found that the picture-based conjoint layout including pictures of food products varying in various ‘food appearance factors’ and/or designed complexity provided fast, reproducible and valid information about children’s visual preferences. Choices made in the picture-based conjoint layout were highly correlated to actual choices of tangible products and further, the method appeared to reflect actual choice better than hedonic evaluations. On basis of our conclusions we recommend that future studies of children’s preferences should focus more on the use of visual presentations of food products compared to traditional hedonic evaluations of tangible food products. The visual presentation elucidates factors important in the modelling of foods in a healthier direction within a short time span and without satiating children.

Our studies revealed that especially colour plays a significant role to children’s preferences. Future research should further investigate the role of colour on children’s preferences, but in general, more research is needed about the specific determinants for food being appealing to children. Exact information on children’s preferences is very essential in new product development of healthier food products targeted children. The information also provides parents, kindergarten teachers, and cantinas at schools with knowledge that may assist production of healthier foods which children like to eat.

The studies on children’s taste preferences provided information on perceptions, preferences, liking and wanting for various food products and established a basis for further development of healthy foods. The potential of masking strategies was another important aspect of our study as results showed that masking was a highly efficient method to model foods in a healthier direction. Our conclusions emphasize that more attention ought to be put into enhancement and suppression of sensory attributes and food components in other food categories to optimize children’s preferences and food choices.
Designed complexity was another strategy of food modelling, which was found successful in the present project. Results illustrated that an increased level of designed complexity increased both liking and visual preferences among children. In this project, designed complexity served as an approximation to perceived complexity and results demonstrated that the two attributes were highly correlated from an adult point of view. However, much more research should focus on how to evaluate perceived complexity. In general, the literature on evaluation of perceived complexity is scarce but when it comes to perceived complexity by children, the research is far behind.

Experiments exploring how to evaluate children’s perception of complexity are required since the degree of perceived complexity is suggested to be important for children’s preferences. Our experience in working with children made us doubt that children know the concept ‘complexity’ but it may be an approach to use words as novelty, intensity or surprisingness or to use alternatives as drawings or blocks to illustrate their degree of perceived complexity. Therefore, we would like to repeat our study on increased designed complexity in FMPs (Paper 6) with an additional dimension namely measurement of perceived complexity by children.

This project proved that combining increased designed complexity of foods with mere exposure was highly effective in modelling of children’s liking whereas mere exposure to least complex foods did not change/or decreased liking. These results highly agree with the collative theories of Berlyne. Approaches in which mere exposure and in-home testing with children are combined would add valuable results to the existing knowledge. By performing in-home testing we avoid the contextual challenges existing when performing test at schools since some children may perceive the test situation as an appreciation which may bias the results.

The main parts of the studies performed during this project revealed various segments of children based on background characteristics according to food preferences, liking and wanting which emphasizes the importance of analysing data at both an individual level and at group level.
Research should focus more on the examination of segmentation of children as it may elucidate reasons for differences in preferences.

Finally, as none of the studies presented in this thesis included long-term follow-up studies on children’s preferences after the interventions, it will be interesting to explore a more long-term effect of the intervention in future experiments since such results will show the real effects of the intervention.

During this PhD project examples of how modelling of children’s food preferences and food products simultaneously affects children’s preferences are investigated. I hope that the results will contribute as a part of the strategy concerning an increase in children’s intake of healthier food products which they like and wish to eat.
8 REFERENCES


Indenrigs- og Sundhedsministeriet (2007). De samfundsøkonomiske konsekvenser af svær overvægt


WHO consultation on obesity. Obesity: preventing and managing the global epidemic 1999;894.


Measuring Children’s Food Preferences: Using Pictures in a Computerized Conjoint Analysis

<table>
<thead>
<tr>
<th>Journal:</th>
<th>Journal of Sensory Studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manuscript ID:</td>
<td>Draft</td>
</tr>
<tr>
<td>Wiley - Manuscript type:</td>
<td>Original Article</td>
</tr>
<tr>
<td>Date Submitted by the Author:</td>
<td>n/a</td>
</tr>
</tbody>
</table>
| Complete List of Authors: | Olsen, Annemarie; University of Copenhagen, Food Science / Sensory Science  
Kildegaard, Heidi; Aarhus University, Department of Food science  
Gabrielsen, Gorm; Copenhagen Business School, Centre for Statistics  
Thybo, Anette; Aarhus University, Department of Food Science  
Møller, Per; University of Copenhagen, Faculty of Life Sciences, Food Science |
| Keywords: | experimental design, consumer studies, food science, sensory science, product optimization |

Abstract: The aim of this study is to investigate food preferences in children by using pictures of foods presented on a computer screen in a conjoint manner, hedonic rating and choice test. In total, 300 children from schools in Copenhagen participated in the study. Two product cases were selected; 32 buns and 8 juices. Pictures of the products were presented and evaluated on a computer screen using conjoint analyses. Right after the test, four buns and two juices (tangible products) chosen to span the preference spectrum, were hedonically evaluated with regard to liking of appearance and taste. Finally, an actual product choice was performed by having the children choose between two buns and two juices. Results showed that the computer evaluations with pictures of foods provided fast, reproducible and valid information about the children’s food preferences, and in some regards reflected actual product choices better than hedonic evaluations.
Measuring Children’s Food Preferences:

Using Pictures in a Computerized Conjoint Analysis

Running title: Measuring Children’s Preferences Using Pictures

A. Olsen\textsuperscript{a*}, H. Kildegaard\textsuperscript{b}, G. Gabrielsen\textsuperscript{c}, A. K. Thybo\textsuperscript{b}, and P. Møller\textsuperscript{a}.

\textsuperscript{a}Department of Food Science, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 30, 1958 Frederiksberg C, Denmark.

\textsuperscript{b}Department of Food Science, Faculty of Agricultural Sciences, Aarhus University, Kirstinebjergvej 10, 5792 Årslev, Denmark.

\textsuperscript{c}Centre for Statistics, Department of Finance, Copenhagen Business School, Solbjerg Plads 3, 2000 Frederiksberg, Denmark.

*Corresponding author: Telephone: +45 35 33 10 18. Fax: +45 35 33 35 09. E-mail: ano@life.ku.dk (A. Olsen)
Abstract

The aim of this study is to investigate food preferences in children by using pictures of foods presented on a computer screen in a conjoint manner, hedonic rating and choice test. In total, 300 children from schools in Copenhagen participated in the study. Two product cases were selected; 32 buns and 8 juices. Pictures of the products were presented and evaluated on a computer screen using conjoint analyses. Right after the test, four buns and two juices (tangible products) chosen to span the preference spectrum, were hedonically evaluated with regard to liking of appearance and taste. Finally, an actual product choice was performed by having the children choose between two buns and two juices. Results showed that the computer evaluations with pictures of foods provided fast, reproducible and valid information about the children’s food preferences, and in some regards reflected actual product choices better than hedonic evaluations.

Practical applications

The paper describes a new combination of methods for measuring food preferences in children using pictures of foods manipulated on visually apparent product attributes in a computerized conjoint analysis. Results were reproducible, and in some regards products choices performed in the picture-based computer program reflected actual choices of tangible products better than hedonic evaluations of appearance or taste. Thus, using pictures in a computerized conjoint analysis facilitates fast and reliable measurement of food preferences in children, and enables direct evaluation of the impact of individual product attributes. The method is easy and inexpensive to use, requires little time and effort from participants, is suitable for online testing, and can quickly be applied to high numbers of participants. Therefore, it provides a convenient tool whenever information about food preferences is desirable; for instance meal planning in (school) canteens and restaurants, planning demand for goods in grocery stores, and particularly for product development.

Key words: Food preference, visual preference, children, conjoint analysis, buns, and juices.
Introduction

Children are customers on one of the largest markets in many parts of the world (Popper & Kroll 2005), and they are more involved in choosing what to buy, use and eat today than they have ever been before (Chambers 2005). Therefore, it is important to understand what drives children’s food choices. Taste preferences are particularly important as they are the primary predictors of children’s food selection and consumption (Birch 1999).

Children’s preferences can be measured in many ways (Guinard 2000). Obviously, tasting a food can reveal liking of that specific product in either qualitative or quantitative measures. However, this procedure is tedious, expensive, impractical in large scale, and has the pronounced disadvantage that children can only taste a limited amount of foods before getting satiated, which might affect their evaluations.

An alternative method is the use of pictures. This method focuses on visual appearance, and generally appearance is often the first sensation to arouse interest in a given food (Lawless 2000). Moskowitz (1994) has shown that children actually pay more attention to visual inputs (e.g. appearance, color, and amount) as drivers of liking than adults.

Realism of product stimulus, i.e. how well the representation resembles the actual product, is an important factor known to influence validity. The use of pictures enhances task realism and validity in product categories where choices strongly depend on visual inspection of products (Jaeger et al. 2000; Vriens et al. 1998). The stimulus format should get respondents to use the same task simplification strategies as they would in the market place (Loosschilder et al. 1995).

The use of non-tasting methods such as photographs of foods has previously been applied in various studies with children. In a comparison of reliability (test-retest) of 3-5 years old children’s food preferences using three different stimuli modalities, it was found that tasting foods produced the most reliable results (r=0.81), followed by looking at photographs (r=0.75), and food models (r=0.52) (Guthrie et al. 2000). In another study, 3-5 years old children’s preferences for fruits and vegetables were successfully assessed with hedonic evaluations of pictures on a computer screen (Jaramillo et al. 2006). The study showed high reliability (r=0.73), and assessment of predictive validity based on both observations and measurement of plate waste also showed good agreement between preferences and observed consumption. High reliability (ICC=0.7-0.8) were also observed in a study with 4-6 year-old children, where preferences for fruits and vegetables were measured quite similarly with hedonic evaluations of pictures on a computer screen (Vereecken et al. 2010).

Finally, preferences for healthy and unhealthy choices of foods were assessed in 3-8 years old...
children using photographs (Calfas et al. 1991). Again, food preference measures showed high reliability ($r=0.70$), and the agreement between stated preferences and actual choice of tangible foods was high (66%). Altogether, these studies show promising applications of using photographs in preference testing. However, it is a necessary prerequisite that children are familiar with the foods they are looking at, so their evaluations will indeed be based on liking rather than lack of familiarity (Jaramillo et al. 2006).

In adults, the use of pictures has been applied in even more advanced ways, for instance in conjoint analyses with varying product attributes within a meal (Reisfelt et al. 2009), using captions to elaborate on product information regarding e.g. price and eating situation with fruits (Jaeger et al. 2000), within product development to investigate preferences through computer modeled pictures for pears (Gamble et al. 2006), acceptance and expectations for food bars (Mahanna et al. 2009; Mahanna & Lee 2010), and passion-fruit juice (Deliza et al. 2003), or to measure quality perception of beef (Brunsø et al. 2005).

Reasons behind consumer preferences are not always obvious, and most consumers do not intellectualize a choice/task, and might not have conscious access to mental processes underlying their preferences (Wilson et al. 1996). Rather, consumers choose intuitively, and as a consequence only the product attributes that are strongest will drive product choices (Raz et al. 2008). A distinct advantage of conjoint analyses is that they make it possible to identify the contribution from individual product attributes driving acceptance and rejection (Moskowitz & Silcher 2006). The use of pictures for preference evaluation through conjoint analyses seems promising for testing adults. However, the suitability of these methods has not yet, to the extent of the authors’ knowledge, been explored in studies with children. Therefore, the aim of this study was to investigate the suitability of these methods for application in school children of various ages.

The objectives were to investigate: a) Reproducibility of picture-based product choices, and b) Method predictability; relationship between picture-based product choices, liking scores, and choices of real products.
Materials and Methods

Participants
The project was carried out in Copenhagen (Denmark) in the Spring of 2008. In total, 300 children from 14 classes and 6 different schools participated. The children were tested twice: 284 children participated at test day one, 263 children at test day two, and 247 children participated in both test days. Participants are described in table 1.

The children were recruited from two age groups; “kids” in the 3rd and 4th grade (9-11 years old) and “adolescents” in the 7th and 8th grade (13-15 years old). Teachers and parents were thoroughly informed about the study, and participation was completely voluntary. Children were asked about food allergies and color blindness prior to participation.

Stimuli: Juices and Buns
A solid and a liquid stimulus were included; buns and juices, which varied on a number of attributes. High quality pictures were taken of each bun and juice separately. The pictures were presented in a specialized computer program (described below).

The buns were cut in halves and presented with the upper part slightly staggered from the bottom part. They were all around the same size and shape (hexagonal), but differed on five attributes in a dichotomial (0/1) manner: 1) Color (white/dark brown), 2) Butter (without/with), 3) Pattern in the crust (without/with), 4) Topping (without/with), and 5) Seeds in the crumb (without/with). The product attributes were coded with 0 and 1, respectively, and thus used for generating codes for each bun. For instance, bun “01100” is a white bun, with butter, with pattern, without topping, and without seeds in the crumb. The combinations resulted in 32 ($2^5$) different buns. The dark brown color was achieved by malt addition. The buttering consisted of butter, and a small package of butter was shown next to the buttered buns (as most Danish children clearly distinguish between butter and margarine). The pattern consisted of small holes on the top bun. The topping consisted of rye flour. The seeds were a mixture of linseed, durum wheat, sunflower, and sesame. The buns were prepared by Easyfood A/S (Kolding, Denmark).

The juices all had a base of apple juice, but differed on three attributes in a dichotomial (0/1) manner, namely: 1) Color (yellowish brown/red), 2) Color intensity (low/high), and 3) turbidity.
These combinations resulted in 8 \(2^3\) different juices. The red color was achieved through addition of strawberry, elder flower, and chokeberries. The color intensity was increased by adding caramel color in the yellowish brown juices, and by adding chokeberry concentrate in the red juices. The turbidity was increased by using unfiltered juice for the yellowish brown juices, and by adding strawberry pulp to the red juices. The juices were prepared by Rynkeby A/S (Ringe, Denmark).

Children were not informed about the specific attributes by which the products differed. This information could have put them in an analytical frame of mind (introspection) and affected their responses (Wilson & Schooler 1991). Rather, they were asked to base their choices on overall opinions.

**The experimental layout**

The computer program consisted of two separate parts; a pictorial part and a questionnaire part. The pictorial part was based on discrete choices in a conjoint analysis. It was arranged in a \(2^k\)-factoral design with 8 pictures presented simultaneously on the screen constituting one block (see *figure 1*). For each block, children selected first their most, then their second most, and finally their least preferred choice by clicking on the picture. When a picture was selected it disappeared, and the remaining pictures in the block changed their positions in a randomized manner before the next choice was made. The whole procedure resulted in an incomplete ranking of the 8 products comprising a block. The program was specially developed for this experiment. It was written in MATLAB (MathWorks Inc., MA, USA), and installed on 4 identical laptops (Toshiba, Satellite Pro A200, Denmark).

For juices, all 8 pictures fitted into a single block. For buns, the pictures were arranged in 4 blocks each consisting of 8 pictures. The block content was constant and balanced across product attributes, but their presentation order was randomized. This design enables statistical independent estimation of all main effects and two-way interactions.

The questionnaire part consisted of questions on demography, physical activity, hunger and thirst, frequency of consumption and liking of rye bread, white bread, juice, and other sweet drinks, and general eating habits. These data will be presented elsewhere. In the following, all questions are described in English, but they were asked in Danish.
Design

The study consisted of two separate parts; termed “test day one” and “test day two”, which both lasted about one and a half hour pr class and were separated in time by four weeks. The children were tested in their usual surroundings at the schools; in (or near) their classroom, that is in an environment which was familiar to them. An overview of the study design is shown in table 2.

Test day one: The children first completed the pictorial part on buns, then the pictorial part on juices, and finally the questionnaire part. Children were told that they were looking at apple juices and apple juices added red fruits. They were not given additional information about the buns. The laptops were arranged in pairs with a trained researcher in the middle and two children around. The screens were positioned in an angled manner to avoid children from seeing each other’s choices. The researcher reminded the children on type of choice (most or least preferred) in the pictorial part and, when necessary, read aloud the questions for the youngest children in the questionnaire part. Finally, the children’s height (SECA Leicester portable height measure, Medisave, UK) and weight (Tanita, BWB-600, Tanita Corporation, Japan) were measured.

Product selection for test day two: After test day one, children’s choice frequencies were analyzed in order to select products to bring at test day two. These products were intended to reflect a preference continuum from least to most preferred products. To avoid exceeding the children’s attention span, and reduce the risk of satiation, it was decided to bring four buns and two juices for the hedonic evaluations.

The ranks within each block were scored such that each first choice was assigned a value of +2, a second choice was assigned +1, a least preferred choice was assigned -1, and products not chosen were assigned 0 (Reisfelt et al. 2009; Markussen 2008). In the following, these rank scores constitute the “picture-based data”. Based on these values, a Total Product Score (TPS) was calculated for each product by summing the score over all children - see figure 2 and 3. A high TPS indicates a preferred product, whereas a low TPS indicates an unpreferred product.

Based on the results from test day one, it was decided to produce a white bun (00000, TPS = 190), a white bun with butter and pattern (01100, TPS = 117), a dark brown bun (10000, TPS = 76), and a
dark brown bun with butter, topping\(^1\), and seeds in the dough (110111, TPS = -14). For the juices, a yellowish brown juice low in both color intensity and turbidity (0000, TPS = 174) was chosen along with a red juice high in both color intensity and turbidity (1111, TPS = -37).

**Test day two:** Children repeated the choices of buns and juices on the computer screen as on test day one. Afterwards, they made hedonic evaluations of appearance and taste of the 4 buns and 2 juices. Finally, they made an actual product choice of buns and juices (tangible products) to take with them. To avoid confusion, buns were always evaluated first and juices last. The serving orders of the different buns and juices were randomized throughout the study, and during the hedonic evaluations, all products were assigned a random 3-digit number.

**Hedonic evaluations:** For evaluations of appearance and taste, a 5-point smiley scale with the descriptors “very bad”, “bad”, “okay”, “good”, and “very good” was used (Chen et al. 1996). The questions were phrased: "How much do you like the appearance/taste of this bun/juice. The questionnaire was made as a little booklet showing only one question at a time. The children first rated appearance of each of the 4 selected buns and 2 juices from one setup, where products were presented similarly to the ones at the pictures. They then moved to another setup for tasting, where the products were presented with a quarter of each bun and 5 cl of each juice. Children were instructed to taste as much as they felt necessary to decide on a judgment. They rated the products one at a time, and prior to each tasting they took a sip of water for palate cleansing. To avoid peer influence, children were instructed not to make “faces” or comment on the products, and the tables were arranged in the classrooms to minimize the field of vision between them.

**Product choices:** The children were offered a bun and a juice to take with them. They were asked to choose between a white and a dark brown bun as well as between a yellowish brown and a red juice (served in a 25 cl juice box with the content illustrated in front of the packaging), and the real choice data were registered. The products were similar to the ones used in the previous parts of the study (bun 00000 and 10100, juice 000 and 100). When choosing, each child was isolated from the others, and they could not see the children, who had already made their choices.

\(^1\) Due to a misdelivery, the topping on this bun was comprised of sunflower seeds and oatmeal instead of rye flour.
Data analyses / Statistics

Reproducibility between test days was compared by – for each product attribute - calculating Pearson correlation coefficients between each child’s individual product attribute (PA) estimates (main effects on the individual level) collected at test day one and two respectively (see models below), and sub groups were compared with 2-tailed t-tests. Data from the pictorial part of the pc program (the individual product rank scores) were analyzed for each day separately as a general linear model. Using a generic notation the model becomes: Model for juices: The score for child i on picture p is denoted $s_{pi}$. The expected value of $s_{pi}$ is modeled by $E(s_{pi}) = \alpha_i + \beta_{1i} \cdot PA_{1p} + \beta_{2i} \cdot PA_{2p} + \beta_{3i} \cdot PA_{3p}$, where $PA_{kp}$ is 0 or 1, corresponding to absence or presence of juice attribute k in picture p. Model for buns: The score for child i on picture p is denoted $s_{pi}$. The expected value of $s_{pi}$ is modeled by $E(s_{pi}) = \alpha_i + \beta_{1i} \cdot PA_{1p} + \beta_{2i} \cdot PA_{2p} + \beta_{3i} \cdot PA_{3p} + \beta_{4i} \cdot PA_{4p} + \beta_{5i} \cdot PA_{5p}$, where $PA_{kp}$ is 0 or 1, corresponding to absence or presence of bun attribute k in picture p. In this way $\beta_{ki}$ becomes the preference of presence of product attribute k for child i for juice and buns, respectively. For buns, the model was also adjusted for effect of blocks.

Hedonic evaluations of taste and appearance were analyzed by one way ANOVA. Product choices (of tangible products) were analyzed by logistic regression models. Data from the pictorial part of the pc program and hedonic evaluations for appearance and taste were compared using the hedonic evaluation score as dependent variable and including children’s individual product attribute estimates ($\beta$ coefficients) calculated from the models described above using regression models. Choice data was analyzed with a logistic regression model. The level of significance was set to 5%. Analyses were performed in SAS 9.0 and SAS JMP 8 SAS Institute Inc., Cary, NC, USA.
Results

Picture-based data: Choices of buns and juices from test day one are shown in figure 2 and 3; data from test day two are not shown. The distribution of bun choices (figure 2) shows a clear tendency towards more choices of white buns compared to dark brown buns. Likewise, yellowish brown juices were chosen more often than red ones (figure 3). A thorough analysis of product attribute importance has been performed, but is outside the scope of this paper.

(Figure 2 and 3)

Reproducibility: When comparing children’s individual product attribute estimates between test days, a high reproducibility was seen for most attributes. For buns, the overall correlation coefficients were: Color: 0.76 (p<0.0001), butter: 0.63 (p<0.0001), pattern: 0.39 (p<0.0001), topping: 0.51 (p<0.0001), and seeds: 0.51 (p<0.0001). Likewise for juices: Color: 0.52 (p<0.0001), color intensity: 0.25 (p<0.0001), and turbidity: 0.30 (p<0.0001). Reproducibility for all product attributes was compared between the two age groups (2-tailed t-test), and a similar analysis was made on gender, but no significant differences were found (data not shown).

Hedonic evaluations: Hedonic evaluations of buns and juices are shown in figure 4. To test for differences in evaluations of appearance and taste between products at the aggregated level, the 4 buns were compared with a Tukey test, and the 2 juices with one way ANOVA. As all children evaluated all of the products, the observations are not strictly statistical independent; however, this is of minor importance.

For buns (figure 4, left part), there were no differences in appearance between the white buns, which were liked better than the dark brown buns, but the dark brown buns differed from each other. For taste, the white bun with butter and pattern (01100) was liked more than the other buns, which did not differ from each other. For juices (figure 4, right part), evaluations of appearance and taste were remarkable similar in both products, but a significant difference was seen between the juices for appearance (p<0.0001) and taste (p<0.0001) with the yellowish brown juice with low color intensity and low turbidity (000) being strongly preferred over the red juice with high color intensity and high turbidity (111).

(Figure 4)
Predictive value – hedonic evaluations: The predictive value of the picture-based data was assessed using the hedonic evaluation scores for liking of appearance of buns (table 3) and juices (table 4) as dependent variables to be explained by the individual product attribute estimates calculated from the picture-based data (the individual rank scores) using logistic regression. Picture-based data from test day two was used, as it was collected right before the hedonic evaluations. Model for juices:

Expected hedonic liking of appearance score for child i = PA_{1i} + PA_{2i} + PA_{3i}.

Model for buns:

Expected hedonic liking of appearance score for child i = PA_{1i} + PA_{2i} + PA_{3i} + PA_{4i} + PA_{5i}, where PA are generic symbols for product attributes of buns and juices, respectively. A similar analysis was performed for taste evaluations (data not shown).

The binomial coding of product attributes are just used for naming the products, and are not directly related to the product attribute estimates. Due to the design and the way of scoring, each individual product estimate can assume values between -1 and +1, representing the estimated effect of absence (“0”) and presence (“1”) of that product attribute. Product attribute estimates close to 1 indicate preference for that specific attribute being present, whereas product attribute estimates close to -1 indicates preference for that specific attribute being absent. Therefore, size and sign of the product estimates indicate children’s preferences for the corresponding product attributes within each of the selected 4 buns and 2 juices.

For all buns, color was the most important product attribute, and the sign of the product attribute estimates were negative for white buns, and positive for dark brown buns. Likewise, butter was found to have high importance in most buns, and in particular for the buttered white bun (01100), and with signs following that of color. Pattern and topping was not important in any bun. Seeds in the dough had some importance, in particular for the dark brown bun with seeds (11011), and again the sign was positive when the product attribute was present and negative when absent.

For juices, color was also found to be the most important product attribute, in particular for the red juice (111). Color intensity had some importance and turbidity even more. For all product attributes, the signs of the estimates were positive when the product attribute was present and negative when absent.

Models for taste data (not shown) resembled the models for appearance with regard to the signs of the product attribute estimates, however, these models described much less of the variation in the data for buns (namely 11.61 %, 26.44 %, 7.60 %, and 11.80 %, respectively) and juices (6.68 % and 8.10 %).
Predictive value – product choices: When choosing between a dark brown and a white bun, most children (186 children; 71.26 %) selected a white bun compared to the dark brown bun (75 children; 28.74 %). For the juices, an even larger group chose the yellowish brown juice (193 children; 74.42 %) compared to the red (66 children; 25.58 %).

The prediction of product choice of buns (Table 5) and juices (Table 6) from the picture-based data (test day two) was assessed using a logistic regression model. The product choices were scored in a dichotomial manner; white bun (0) and dark brown bun (1) and likewise for juices; yellowish brown juice (0) and red juice (1), and used as dependent variables. As for the hedonic evaluations, the individual product attribute (PA) estimates calculated from the picture-based data (the individual rank scores) from test day two were used as explanatory variables.

In buns, color and seed had the largest influence on product choices. Children who chose dark brown buns with seeds in the crumb in the computer program also selected the dark brown bun when offered as a tangible product. For juices, color was also the most influential product attribute. Children who chose red juices in the computer program also chose the red juice when offered. The model fit was 35.58 % for buns and 12.89 % for juices.
Discussion

Picture-based data: As the distribution of bun choices illustrated (figure 2), white buns were by far the most popular, and the simpler bun the more popular it was. The three most popular buns (TPS>150) were all white, completely simple or with either butter or pattern. Preferences for refined types of bread among children have also been observed by Delk & Vickers (2007), who reported decreases in liking scores with increasing whole wheat concentrations. From a health perspective, this is less optimal as white bread products are often low in wholegrain and fibers compared to their darker counterparts.

The distribution of juice choices (figure 3) showed that children preferred yellowish brown juices. The two most popular juices (TPS>150) were both yellowish brown juices – with or without high color intensity. This is probably because yellowish brown is the standard color for apple juices. Mixed juices are not uncommon in Denmark, but probably less familiar than the apple juice.

For simplicity, possible explanations of children’s preferences and product choices are discussed in the section comparing the different methodologies.

Reproducibility: Correlation coefficients for the various product attribute estimates were quite high, reflecting that the method provided reproducible results between test days. In particular, color and butter for buns, and color for juices appeared to be consistently selected attributes. Color is a strong visual cue, and these observations substantiate the high influence of visual input in children suggested above (Lawless 2000; Moskowitz 1994).

No differences in reproducibility between age groups or genders were observed. Likewise, other studies found none or few differences in reproducibility between boys and girls, but some found a tendency for reproducibility to increase with age (Leon et al. 1999; Guthrie et al. 2000; Jaramillo et al. 2006; Calfas et al. 1991). However, these studies primarily investigated children that were younger than the ones included in our study, and with younger age groups, cognitive performance might vary more.

Hedonic evaluations: When comparing the different types of preference data obtained in this study, the most direct comparison is between picture-based data (figure 2 and 3) and the hedonic evaluations (figure 4) as they can be directly compared for the various products. The hedonic evaluations of appearance and taste showed some interesting deviations from the picture-based data in the bun case. With regard to appearance, white buns were preferred over dark brown buns, and
the simple dark brown bun (10000) was preferred over the more complex one (11011). This is in accordance with what would be expected from the picture-based data. However, the picture-based data showed large differences between choices of white and dark brown buns, and the actual size of the differences in the hedonic evaluations do not seem as pronounced. These differences were more pronounced for the taste data, where the white bun with butter and pattern (01100) was liked the most. However, the relative differences between buns were small, reflecting that children liked all selected buns around equally well. This finding has some interesting implications: It illustrates the difficulties in measuring preferences and how different methodologies can provide different results. In addition, it reveals an interesting challenge from a health perspective: If children perceive their liking of buns (and possibly other bread products) to be different based on appearance, but less different when the products are tasted, making children taste darker types of bread could be a way of making them realize that they might actually like these products.

For juices, the hedonic evaluations of appearance and taste were more directly in accordance with the picture-based data. The picture-based data showed a high preference for yellowish brown juices, and this was also found in the hedonic evaluations. The high concordance between the different measures in the juice case might be due to the fact that only two juices from various ends of the preference spectrum were included. This could indicate that if liking levels of products are clearly differentiated, different measures might provide similar results.

Predictive value – hedonic evaluations: When analyzing hedonic evaluations of appearance using product attribute estimates as explanatory variables, it was evident that for buns (table 3), color was the most important product attribute, and the sign of the product attribute estimates were in accordance with what would be expected (negative for white buns, and positive for dark brown buns). Likewise, butter was found to have high importance in buttered buns (01100 and 11011). Pattern and topping were found to be less important, whereas seeds in the crumb were particularly important in the bun having this characteristic (11011).

For juices (table 4), color was also found to be an important attribute, and again the sign of the product attribute estimates were in accordance with what would be expected; negative for the yellowish brown juice (000), and positive for the red juice (111). Color intensity also had an influence, but not as much as turbidity, for which the product attribute estimates were clearly negative for the clear juice (000), and positive for the turbid juice (111).
The high impact of color found in both product cases substantiated its importance for children (Moskowitz 1994; Lawless 2000), and this was also seen in its high reproducibility. Overall, the product attributes indicated that a popular bun can be characterized as being white, with butter, without pattern, without topping, and with seeds in the crump. Likewise, a popular juice can be characterized as being yellowish brown, with ordinary color intensity and ordinary turbidity. These are both descriptions of quite simple products, which can certainly be optimized in a healthier manner. For instance, if children are positive toward seeds in the crump, this could be a starting point for making the buns healthier, while still acceptable.

The levels of variation explained by the bun models were moderate (29-38%), probably because these models are quite simple excluding any interaction or background data. For the juice models, it varied from poor to moderate (15% and 37 %, respectively), with the least liked juice showing the highest degree of explained variance. This might reflect that children agreed on the attributes causing them to dislike the red, intensely colored, turbid juice (111), but disagree on why they like the clear, yellowish brown juice (000). The poor to moderate levels of variance explained by the models also reflect that children vary considerably in their product choices, which makes it difficult to generalize on their preferences.

The levels of variation explained by the models for taste of buns (8-26 %) and juices (7-8 %) were considerably lower than the corresponding models for appearance. This is not surprising as the models are based on the picture-based data, i.e. pictures (visual input), and this finding thus reflects that hedonic information about taste cannot be deduced from visual stimuli.

Predictive value – product choices: As for the hedonic evaluations, when analyzing product choices using product attribute estimates from the picture-based data as explanatory variables, it was evident that for buns (table 5) and juices (table 6) alike, color was the most important product attribute, with seeds in the crumb also being a main determinant for buns. The strong influence from color is in accordance with what has been discussed above, and for both cases it can further be explained by color being the one parameter that differed between the two products from which the children could choose. None of the offered buns had seeds in the crumb, but this product attribute might be associated with darker types of bread, which could explain why it follows the choice pattern of the dark brown color.

The amount of variance described by the models varies considerably for the two product cases with the bun case (35.58 %) being almost threefold the level as the juice case (12.89 %). This illustrate
that choice consistency across methods might depend on product category or perhaps even the product itself. However, it could also be associated with the way the products were presented when offered to the children, as buns were presented exactly as seen on the computer screen (with no packaging), whereas juices were presented in glasses on the pictures, but for practical reasons offered in juice boxes. Additionally, product interaction might also play a role. During the hedonic evaluations the children tasted the white (00000) and dark brown (10000) buns, as well as the yellowish brown juice (000), but not the red juice (100) that was offered. This could have made the children more confident in their choices of buns. Finally, it must be taken into account that the children could only make a very simple choice between two products. Presumably, the level of explained variation would have increased considerably if the product selection had been broader and spanned more product attributes. However, even with these simple product choices, the picture-based data provided models for children’s choice behavior explaining from poor to moderate levels of variance, and thus indicating (but not completely confirming) method validity.

Comparison of picture-based data, hedonic evaluations and product choices: Interestingly, for both buns and juices the picture-based data in some regards seemed to reflect children’s actual product choices better than the hedonic evaluations of taste and appearance, as the product choices also revealed a high preference for white buns and yellowish brown juices. Prediction of consumer behavior is a key concern in many settings, and as product choices can be interpreted as an actual manifestation of consumer behavior, the use of pictures in computerized conjoint analyses shows very promising applications (Reisfelt et al. 2009; Gamble et al. 2006; Loosschilder et al. 1995; Vriens et al. 1998).

The picture-based data suggested large differences in children’s liking of buns, but this was not seen in the hedonic evaluations, whereas the product choices also revealed large differences. These findings are in contrast to Jaeger et al. (2000), who compared performance of physical stimuli and pictures in consumer’s choice decisions for pre-packed apples, and found no substantial differences between methods. However, their design was different from ours; choice decisions were simpler and identical for pictures and tangible products, and this will most likely increase the likelihood of similar results. It should also be noted that the relatively small differences observed between buns in our hedonic evaluations actually were in accordance with what would be expected from the picture-based data, and we do not observe contradictory findings between methods.
It is very likely that some of the differences observed between methods cannot be ascribed to task alone but rather to contextual influences. In this study, both tasks and product sets varied across methods; the picture-based choice part was an incomplete ranking with 32 buns and 8 juices, the hedonic evaluations were category scaling (rating) with 4 buns and 2 juices, and the choices of tangible products were between 2 buns and 2 juices - and was conducted after the products were tasted. When tasks are not identical, children might respond differently towards them due to a number of reasons such as cognitive level, task difficulty, varying involvement of senses (sight, smell, and taste), as well as familiarity with, interest in, and understanding of task. An additional concern is the inherent difference between choice and rating tasks; none or even small differences in liking might be reflected in consistent differences in choice, which can also be affected by factors irrelevant for liking (e.g. considerations for health and cost). Intuitively, it thus seems likely that a choice task will be a better predictor of another choice task than other types of tasks such as hedonic ratings – and this also seems to be the case in this study (although not explicitly tested). This makes the picture-based choice task even more interesting as in many cases, prediction of consumer choices are more interesting than prediction of hedonic preferences. Another issue is, as suggested above, that consistency might vary with product category. It is likely that for some products (or even product attributes), consumer’s decision strategies are better developed, and perhaps more stable. Finally, the number of product attributes might have been too high for some children to embrace at once, and as we did not specifically inform about the attributes, they might not discover all of them.

At least for the bun case, these observations also illustrate that children do not seem to make their product choices based on immediate experiences (i.e. they just evaluated white and dark brown buns quite similarly, and still selected white buns), but rather some pre-programmed knowledge/memory of preferences for white buns. Similar observations were done in a study comparing adults’ preferences for refined and whole wheat bread, where many participants, who preferred the whole wheat bread, still chose the refined bread (Bakke & Vickers 2007). These findings challenge the use of liking as a primary predictor of actual food choices. One explanation might be that white bread is a more familiar product; children (2-18 years) on average consume around six times more refined bread than whole wheat (Harnack et al. 2003). Therefore, to improve children’s eating habits and expand their product experiences, it is of utmost importance to give them positive experiences with a wide spectrum of products, so this pre-programmed knowledge that seems to govern their choices can be expanded to include healthier and more complex products.
In addition, this picture-based method could potentially help identify products that are as healthy as possible, but still acceptable.

For the juices, the picture-based data was very much in line with hedonic evaluations for both appearance and taste, as well as for the choice data in that the yellowish brown juice was preferred over the red. This could be due to the fact that the juices were simpler products; they varied on a lower number of attributes than the buns, and thus may be easier for the children to evaluate. However, another possibility is that the differences in liking were larger between the products, and this could reflect that hedonic evaluations and product choices may be more consistent in either ends of the preference spectrum. Also, the yellowish brown juices were more familiar to the children, which is an important determinant of their preferences (Birch 1979), and also might influence method validity.

In conclusion, this picture-based method provided reproducible results between test days for both buns and juices, and no differences were observed in reproducibility due to gender or age group. Therefore, using pictures in a computerized conjoint analysis can provide a fast and reliable measure of current preferences on known food stimuli, and reflect choice behavior in the immediate future among children - and presumable other segments of a population. In particular, using this picture-based method makes it possible to obtain information about specific product attributes that are visually apparent, facilitates design of products that consumers find attractive, and makes possible evaluation of “health status” of current preferences by identification of positive drivers (attributes) and evaluation of their healthiness. Importantly, choices performed in the picture-based computer program in some regards seemed to reflect product choices more directly than hedonic evaluations for both appearance and taste.
Acknowledgements

We acknowledge Jakob Lund Laugesen for developing the computer program, Jens Michael Madsen for taking the photographs, as well as the companies Easyfood A/S and Rynkeby Foods A/S for assistance in developing the test buns and juices, as well as supplying them. The Danish Agency for Science, Technology and Innovation are greatly acknowledged for financial support (FøSu-project: Step-by-step change of children’s preferences towards healthier foods, J.nr. 3304-FSE-06-0504). The authors declare no conflicts of interests.
References


Figure captions

**FIG 1.**
EXAMPLE OF SCREEN DUMP (I.E. ONE BLOCK) FROM THE COMPUTER PROGRAM FOR THE BUN CASE.

**FIG 2:** CHOICES OF 32 BUNS AT THE FIRST VISIT (284 CHILDREN).
The buns are numbered in a binomial manner following this order of attributes: 1) Color (white/dark brown), 2) butter (without/with), 3) pattern in the crust (without/with), 4) topping (without/with), and 5) seeds in the crumb (without/with). The first three columns show how many times a certain bun was selected as first, second and last choice. TPS is the Total Product Score and integrates the different choices as a first choice is assigned a value of +2, second choice a value of +1, not chosen is assigned 0, and last choice is assigned -1.

**FIG 3:** CHOICES OF 8 JUICES AT THE FIRST VISIT (284 CHILDREN).
The juices are numbered in a binomial manner following this order of attributes: 1) Color (yellowish brown/red), 2) color intensity (low/high), and 3) turbidity (low/high). The first three columns show how many times a certain juice was selected as first, second and last choice. TPS is the Total Product Score and integrates the different choices as a first choice is assigned a value of +2, second choice a value of +1, not chosen is assigned 0, and last choice is assigned -1.

**FIG 4:** HEDONIC EVALUATIONS OF TASTE AND VISUAL APPEAL FOR 4 SELECTED BUNS (LEFT) AND 2 JUICES (RIGHT).
Measured on a 5-point smiley scale (from 1 = very bad to 5 = very good, ± std.dev., n = 263). The buns and juices are numbered in a binomial manner in the same order as in the method section.
Tables

TABLE 1.
DESCRIPTION OF PARTICIPANTS (MEAN VALUES ± STANDARD DEVIATIONS).

<table>
<thead>
<tr>
<th></th>
<th>“Kids”</th>
<th>“Adolescents”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>n = 154</td>
<td>n = 146</td>
</tr>
<tr>
<td>Gender</td>
<td>81 Girls / 73 Boys</td>
<td>76 Girls / 70 Boys</td>
</tr>
<tr>
<td>Age</td>
<td>9.9 years ± 0.7 years</td>
<td>13.8 ± 0.7 years</td>
</tr>
<tr>
<td>Height</td>
<td>143.1 cm ± 6.7 cm</td>
<td>167.2 cm ± 7.3 cm</td>
</tr>
<tr>
<td>Weight</td>
<td>35.8 kg ± 6.2 kg</td>
<td>58.1 kg ± 10.5 kg</td>
</tr>
<tr>
<td>BMI</td>
<td>17.4 ± 2.1</td>
<td>20.7 ± 3.1</td>
</tr>
</tbody>
</table>

TABLE 2.
OVERVIEW OF THE EXPERIMENTAL DESIGN.

<table>
<thead>
<tr>
<th>Test day One</th>
</tr>
</thead>
<tbody>
<tr>
<td>Picture-based computer program on buns (32 types)</td>
</tr>
<tr>
<td>Picture-based computer program on juices (8 types)</td>
</tr>
<tr>
<td>Demographic questions</td>
</tr>
<tr>
<td>Measurement of height and weight</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pause (4 weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection and production of buns and juices that span the preference spectrum (based on analysis of data from test day one)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test day Two</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition of picture-based computer programs on buns and juices</td>
</tr>
<tr>
<td>Hedonic evaluation of appearance and taste for selected samples (4 buns and 2 juices)</td>
</tr>
<tr>
<td>Product choice among selected samples (2 buns and 2 juices)</td>
</tr>
</tbody>
</table>
TABLE 3.
IMPORTANCE AND DEGREE OF EXPLANATION OF PRODUCT ATTRIBUTES FROM THE PICTURE-BASED
DATA FOR HEDONIC EVALUATIONS OF APPEARANCE IN BUNS. THE ESTIMATES CAN ASSUME
VALUES BETWEEN -1 AND +1, REPRESENTING THE EFFECT OF ABSENCE (0) AND PRESENCE (1) OF
THAT PRODUCT ATTRIBUTE.

<table>
<thead>
<tr>
<th></th>
<th>Bun &quot;00000&quot;</th>
<th>Bun &quot;01100&quot;</th>
<th>Bun &quot;10000&quot;</th>
<th>Bun &quot;11011&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product description</strong></td>
<td>White, no butter, no pattern, no topping, no seeds.</td>
<td>White, with butter, with pattern, no topping, no seeds.</td>
<td>Dark brown, no butter, no pattern, no topping, no seeds.</td>
<td>Dark brown, with butter, no pattern, with topping, with seeds.</td>
</tr>
<tr>
<td><strong>Estimate</strong></td>
<td>-0.48</td>
<td>-0.50</td>
<td>0.65</td>
<td>0.63</td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td>24.50</td>
<td>27.44</td>
<td>45.13</td>
<td>42.91</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>-0.26</td>
<td>0.93</td>
<td>-0.41</td>
<td>0.52</td>
</tr>
<tr>
<td><strong>Butter</strong></td>
<td>4.68</td>
<td>61.24</td>
<td>11.97</td>
<td>19.35</td>
</tr>
<tr>
<td><strong>Pattern</strong></td>
<td>-0.11</td>
<td>-0.04</td>
<td>-0.37</td>
<td>0.11</td>
</tr>
<tr>
<td><strong>Topping</strong></td>
<td>-0.18</td>
<td>-0.21</td>
<td>0.02</td>
<td>0.06</td>
</tr>
<tr>
<td><strong>Seed</strong></td>
<td>-0.51</td>
<td>-0.39</td>
<td>-0.23</td>
<td>0.87</td>
</tr>
<tr>
<td><strong>Total SS (model)</strong></td>
<td>59.10</td>
<td>134.76</td>
<td>79.86</td>
<td>126.10</td>
</tr>
<tr>
<td><strong>Model fit</strong></td>
<td>R-square: 29.29 % (n = 263)</td>
<td>R-square: 38.77 % (n = 263)</td>
<td>R-square: 34.75 % (n = 263)</td>
<td>R-square: 31.77 % (n = 263)</td>
</tr>
</tbody>
</table>

The estimate is the model-based parameter estimate for each product attribute, and SS is the sum of squares.

TABLE 4.
IMPORTANCE AND DEGREE OF EXPLANATION OF PRODUCT ATTRIBUTES FROM THE PICTURE-BASED
DATA FOR HEDONIC EVALUATIONS OF APPEARANCE IN JUICES. THE ESTIMATES CAN ASSUME
VALUES BETWEEN -1 AND +1, REPRESENTING THE EFFECT OF ABSENCE (0) AND PRESENCE (1) OF
THAT PRODUCT ATTRIBUTE.

<table>
<thead>
<tr>
<th></th>
<th>Juice &quot;000&quot;</th>
<th>Juice &quot;111&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product description</strong></td>
<td>Yellowish brown, low color intensity, low turbidity.</td>
<td>Red, high color intensity, high turbidity.</td>
</tr>
<tr>
<td><strong>Estimate</strong></td>
<td>-0.23</td>
<td>0.65</td>
</tr>
<tr>
<td><strong>SS</strong></td>
<td>7.74</td>
<td>62.89</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>0.0003</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Color</strong></td>
<td>-0.02</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Color intensity</strong></td>
<td>0.02</td>
<td>4.84</td>
</tr>
<tr>
<td><strong>Turbidity</strong></td>
<td>-0.35</td>
<td>0.39</td>
</tr>
<tr>
<td><strong>Total SS (model)</strong></td>
<td>25.83</td>
<td>122.17</td>
</tr>
<tr>
<td><strong>Model fit</strong></td>
<td>R-square: 14.82 % (n = 262)</td>
<td>R-square: 36.76 % (n = 263)</td>
</tr>
</tbody>
</table>

The estimate is the model-based parameter estimate for each product attribute, and SS is the sum of squares.
TABLE 5.
PREDICTION OF PRODUCT CHOICE OF BUNS FROM THE PICTURE-BASED DATA COLLECTED ON TEST DAY TWO (SCORING: 0=WHITE BUN, 1=DARK BROWN BUN).

<table>
<thead>
<tr>
<th>Buns</th>
<th>Estimate</th>
<th>L-R ChiSquare</th>
<th>Odds Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Color</td>
<td>1.85</td>
<td>56.53</td>
<td>6.38</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2.Butter</td>
<td>-0.23</td>
<td>0.51</td>
<td>0.79</td>
<td>0.4753</td>
</tr>
<tr>
<td>3.Pattern</td>
<td>-0.08</td>
<td>0.02</td>
<td>0.95</td>
<td>0.8776</td>
</tr>
<tr>
<td>4.Topping</td>
<td>-0.15</td>
<td>0.09</td>
<td>0.86</td>
<td>0.7599</td>
</tr>
<tr>
<td>5.Seed</td>
<td>2.08</td>
<td>13.91</td>
<td>7.98</td>
<td>0.0002</td>
</tr>
</tbody>
</table>

Model fit R-square: 35.58 % (n=261)

The estimate is the model-based parameter estimate for each product attribute, L-R ChiSquare is a measure of the impact of each product attribute, and the odds ratio is a relative measure of effect size, describing the change in chance of product being chosen.

TABLE 6.
PREDICTION OF PRODUCT CHOICE OF JUICES FROM THE PICTURE-BASED DATA COLLECTED ON TEST DAY TWO (SCORING: 0=.YELLOWISH BROWN JUICE, 1=RED JUICE).

<table>
<thead>
<tr>
<th>Juices</th>
<th>Estimate</th>
<th>L-R ChiSquare</th>
<th>Odds Ratio</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.Color</td>
<td>1.07</td>
<td>30.24</td>
<td>2.90</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>2.Color intensity</td>
<td>-0.03</td>
<td>0.02</td>
<td>0.97</td>
<td>0.8888</td>
</tr>
<tr>
<td>3.Turbidity</td>
<td>0.06</td>
<td>0.04</td>
<td>1.06</td>
<td>0.8495</td>
</tr>
</tbody>
</table>

Model fit R-square: 12.89 % (n=258)

The estimate is the model-based parameter estimate for each product attribute, L-R ChiSquare is a measure of the impact of each product attribute, and the odds ratio is a relative measure of effect size, describing the change in chance of product being chosen.
A method to measure the effect of food appearance factors on children's visual preferences

H. Kildegaard a,⁎, A. Olsen b, G. Gabrielsen c, P. Møller b, A.K. Thybo a

aDepartment of Food Science, Faculty of Science and Technology, Aarhus University, DK-5792 Aarslev, Denmark
bDepartment of Food Science, Faculty of Life Sciences, University of Copenhagen, Rolighedsgade 30, 1958 Frederiksberg C, Denmark
cDepartment of Finance, Centre for Statistics, Copenhagen Business School, Solbjerg Plads 3, 2000 Frederiksberg, Denmark

⁎ Corresponding author. Tel.: +45 89 99 34 13; fax: +45 89 99 34 95.
E-mail address: heidi.kildegaard@agrsci.dk (H. Kildegaard).

Article info
Article history:
Received 22 March 2011
Received in revised form 20 June 2011
Accepted 21 June 2011
Available online 28 June 2011

Keywords:
Visual preferences
Children
Conjoint analysis
Food choice
Background variables

Abstract
The aim of the study was to examine children's visual preferences for two food products; yoghurts and smoothies, by using a conjoint layout. In total, 274 children performed an incomplete ranking of 8 pictures formed by three factors each with two levels (2³ design). The three food appearance factors were 'colour', 'visible fruit' and 'portion size'. The children were segmented into one of eight groups given by 2 (grade) × 2 (urban/rural affiliation) × 2 (time of visit), and they completed questionnaires regarding background information. Finally, an actual product choice was performed for the eight smoothies. The children visually preferred the two products without visible fruit and colour had a large influence on visual preferences too. As regards the yoghurts, the children accepted a less simple variant whereas the most preferred smoothie was very simple. Significant synergetic effects between food appearance factors and segmentation factors were found. Additionally gender and ethnicity were found to be influential drivers for food choice.

© 2011 Elsevier Ltd. All rights reserved.

1. Introduction

Children are more involved than ever in choosing which food products to purchase and which products to eat, and their food choices are highly related to their preferences (Berg, Jonsson, Conner, & Lissner, 2003; Birch, 1979). Recently it was found that children's (9–11 years old) preferences for healthy food products were a better predictor of intake than either parental intake or parental attitudes to child feeding (Gibson, Rapoport, & Wardle, 1998). This indicates that children's preferences can be a major obstacle to consume a healthy diet (Guthrie, Rapoport, & Wardle, 2000). In order to guide children to choose healthy foods there is a need for elucidating the factors that drive children's food choice. Research has shown that visual appearance is an essential driver for children's food choices (Leon, Couronne, Marcuz, & Koster, 1999; Marshall, Stuart, & Bell, 2006) as appearance is the first sensation to arouse interest in a given food (Lawless, 2000), and it sets up expectations for the actual sensory perceptions (Gamble, Jaeger, & Harker, 2006; Jaeger & Macfie, 2001; Leon et al., 1999). Moreover, it is important to develop and implement reliable methods to evaluate children's perceptions of various food components leading to a more healthy diet (Moskowitz & Silcher, 2006).

One technique to evaluate the drivers for food choice is the use of pictures, and the validity of using pictures has been established earlier by Jaeger, Hedderley, and Macfie (2001) and Reisfelt, Gabrielsen, Aaslyng, Bjerre, and Møller (2009). Taste information on the foods in the supermarket is rare, forcing the consumers to make decisions based on the appearance of the foods. Appearance properties of a product comprise various visual properties, including colour, size and shape. The perceived properties produce various sensations leading to various degrees of acceptance of the food. Hence, the overall appearance of a food product is essential regarding acceptance or rejection of it (Hutchings, 2003).

Improved skills in computerisation and the increased use of the internet have opened new possibilities in performing visual consumer preference investigations. These visually founded techniques have successfully been applied in various studies (Gamble et al. (2006); Reisfelt et al., 2009; Guthrie et al., 2000; Jaramillo, Yang, Hughes, Fisher, Morales, & Nicklas, 2006; Looschijlder, Rosbergen, & Wittink, 1995; Munkevik, Hall, & Duckett, 2007; Ngapo, Martin, & Dransfield, 2007; Olsen, Kildegaard, Gabrielsen, Thybo, & Møller, unpublished results; Gamble et al., 2006 have investigated preferences for pears in adults by computer modelled pictures of pears, and Gamble et al., 2006 have used pictures to examine adult's visual preferences for various meal components. Also in research with children pictures have successfully been used to esti-
mate preferences. Jaramillo et al. (2006) have found that children's preferences for fruit and vegetables were successfully assessed by hedonic evaluations of digital pictures of the food items. Here test-retest reliability was tested and the overall correlation was 0.73. In another study with 9–14 year old children, visual preferences has been examined in a conjoint analysis by using pictures of food products presented on a computer screen (Olsen, unpublished results). The results showed that the computer evaluations with pictures of foods provided fast and reliable information about children's food preferences. Based on this, it is hypothesised that the computer-based conjoint analysis is a reliable method to determine children's visual preferences. In a conjoint analysis, the participants are presented with a variety of products or pictures, each differing from the others on particular sensory attributes. The participants may be asked to rank their preferences for the various pictures or to make choices between a number of pictures presented to them simultaneously (Jaeger et al., 2001). In the present study the children also completed a questionnaire providing different kinds of background variables. Reisfelt et al. (2009) have obtained background variables and showed that age significantly influenced choice of various meal components in adults. In addition, they have compared urban consumers to rural consumers and found differences in visual preferences for various meal components. Differences in food choice between rural and urban consumers were also found by Cullen and Kingston (2009). Based on these results on adults, it is hypothesised that a segmentation of children's food choice can be defined by grade, urban/rural affiliation, the time of visit and other background variables as well. Grade is included in order to investigate effects of age and time of visit in order to investigate the effects of hunger status.

The aims of this study were (1) to elucidate specific drivers for children's visual preferences for two different food products, yoghurts and smoothies, by the implementation of a picture-based method implemented on computers. The products varied systematically in the food appearance factors, ‘colour’, ‘fruit pieces’ and ‘portion size’. Furthermore the aim was (2) to study the effect of three segmentation factors, ‘grade’ (3rd grade or 6th grade), ‘urban/rural’ affiliation (rural schools or urban schools) and ‘time of visit’ (before lunch or after lunch), on children's visual preferences and food choices. The third aim was (3) to study the effect of background variables such as hunger state, gender, age, ethnicity, BMI z-scores and eating habits on children's visual preferences. Finally the study aimed (4) at elucidating if a correlation between visual picture-based product choices and real product choices exists, i.e. to study the reliability of the picture-based methodology.

2. Material and methods

2.1. Participants

Children from seven Danish public schools, located on Funen, participated in the study. In total, 274 children were recruited. Approximately half the children (n = 152) came from the rural part of Funen, whereas the other half of the children (n = 122) lived in the largest city on Funen, Odense. The children were recruited from two age groups: young children in the 3rd grade (9–10 years old) and older children in the 6th grade (12–13 years old). The participants are described in Table 1.

From the 274 children recruited, 268 completed the ranking test of smoothies, and 252 children completed the ranking test of yoghurt.

Teachers and parents were thoroughly informed about the study and an informed consent was obtained from children's parents prior to participation. The children's participation in the study was voluntary.

| Table 1 |
| Description of participants. |
| 3rd grade | 6th grade |
| Children | n = 152 | n = 122 |
| Gender | 67 girls / 81 boys | 66 girls / 55 boys |
| Age (years) | 9.3 ± 0.5 | 12.3 ± 0.5 |
| Height (cm) | 139.7 ± 6.0 | 158.6 ± 7.7 |
| Weight (kg) | 34.4 ± 7.2 | 48.4 ± 10.0 |
| BMI | 17.5 ± 2.8 | 19.1 ± 2.9 |
| BMI z-scores | 0.4 ± 1.1 | 0.3 ± 1.1 |

The mean values ± standard deviations.

| Table 2 |
| Product codes and the three food appearance factors for yoghurt and smoothie. |
| Product codes | Food appearance factors ‘colour’, ‘visible fruit’, ‘portion size’ |
| 000 | Light red, without visible fruit pieces, small |
| 001 | Light red, without visible fruit pieces, large |
| 010 | Light red, with visible fruit pieces, small |
| 011 | Light red, with visible fruit pieces, large |
| 100 | Dark red, without visible fruit pieces, small |
| 101 | Dark red, without visible fruit pieces, large |
| 110 | Dark red, with visible fruit pieces, small |
| 111 | Dark red, with visible fruit pieces, large |

2.2. Products

The product categories comprised two food products; yoghurt and smoothie, which varied on three food appearance factors each including two levels, ‘0’ and ‘1’.

(1) ‘Colour’ (light red ‘0’/dark red ‘1’)
(2) ‘Visible fruit’ (without ‘0’/with ‘1’)
(3) ‘Portion size’ (small ‘0’/large ‘1’)

The combinations of these food appearance factors resulted in 8 (2*) different yoghurts and 8 (2*) different smoothies, which can be seen in Table 2 and Fig. 1.

As regards yoghurts, the food appearance factor ‘dark colour’ was achieved by adding viscous red colour, extracted from choke berries, to the yoghurt. The food appearance factor with ‘fruit pieces’ was prepared by adding 12% strawberry pieces (0.7 mm × 0.7 mm) to the sample. For the food appearance factor ‘portion size’, the small portion was 100 g and the large portion was 200 g. The yoghurt was presented in transparent bowls (Fig. 1), and they were prepared by Arla Foods amba (Viby J, Denmark).

As regards smoothies, the food appearance factor ‘light red’ colour was achieved by making a smoothie composed of raspberries, whereas the ‘dark red’ colour was achieved by making a smoothie composed of blue berries and banana. In the light red smoothie, the ‘visible fruit’ content was regulated by adding 9% of very small pieces of sliced raspberries and bananas (0.2 mm × 0.2 mm), and in the dark red smoothie, the ‘visible fruit’ content was regulated by adding 9% very small pieces of sliced blue berries and bananas (0.2 mm × 0.2 mm). The small ‘portion size’ was 65 g, whereas the large ‘portion size’ was 145 g. The smoothies were presented in high transparent glasses (Fig. 1). The smoothies were prepared by Rynkeby Foods A/S (Ringe, Denmark).

2.3. Pictures

High quality pictures were taken of each product with a Canon D-20 camera. The photos were taken with an aperture value at F13, at ISO 100 and exposure 1/200. The digital photos were of high-resolution (300dpi Tiff), and stored as JPEG format. The area where
the photos were taken was covered with light-gray photo paper to obtain a uniform background and photo flash was used to ensure constant lighting conditions in the room. The pictures were presented in a specialised computer programme (described below).

2.4. Design of the computer programme

The specialised computer programme used for the presentation of pictures and questionnaires was written in MATLAB (MathWorks Inc., MA, USA), and installed on four identical laptops (HP Elitebook 8530P) with 15.4 inches interfaces. The programme consisted of two separate parts; a pictorial part and a questionnaire part. The pictorial part, of both yoghurt and smoothie, was formed as a conjoint analysis, where all factor combinations were presented simultaneously. It was based on a full factorial design with the $2^3 = 8$ different combinations of pictures presented on the screen. Fig. 1 displays the screen dumps that the children were presented with in the programme. The arrangement of the pictures on the computer screen was randomised.

The questionnaire part included nine questions (see appendix). To ensure independency between the picture and the questionnaire part, the questionnaire part was always the last task in the test sessions.

The programme functioned interactively, forcing the children to make a choice of the picture or question posed by pressing the key marker on one of the displayed response options. The children made discrete choices by selecting their most, second most and least preferred choice, thereby performing an incomplete ranking of the eight products. When a picture was selected, the picture disappeared, and the remaining pictures on the screen changed their position in a randomised manner allowing the children to progress to the next choice.

2.5. Study design

The children were categorised into ‘grades’ (3rd and 6th grades), ‘urban/rural’ (geographic affiliation) and ‘time of visit’ (before lunch and after lunch) (Table 3), and these factors composed the segmentation factors. Each child made an incomplete ranking of eight products comprised by varying the three two-level factors; ‘colour’, ‘visible fruit’ and ‘portion size’.

The study consisted of a single test day for each school class and it lasted about one hour. The time of visit was randomised between urban and rural areas and the children were categorised into 3rd and 6th grades.

2.6. Test procedure

The test session took place in a room near the classroom to ensure that children were tested in a familiar environment. A trained instructor introduced the experiment in detail to the children. Except for clarifying questions, children were told to remain silent throughout the test. During the test sessions, two tables were placed in the middle of the test rooms with a laptop arranged at each side of the table. Hereby two children were able to run the test session simultaneously. At each table, a trained instructor was seated between the two children to ensure concentration and silence and when necessary to read aloud the questions from both the pictorial and the questionnaire part. To avoid putting the children in an analytical frame of mind, they were not informed about the specific food appearance factors by which the products differed, as this information might affect their responses (Wilson & Schooler, 1991). They were asked to base their choices on overall visual preference.

The children completed the pictorial choice part on yoghurt on one computer and continued to the next computer featuring pictures of the smoothies and the questionnaire part.

2.6.1. The questionnaire

The questionnaire part included 9 questions that focused on detailed information about state of hunger, gender, age and ethnic origin. Furthermore, it compiled questions on the preferences
and average consumption of some specific food items using a five-point category scale. This part of the questionnaire was constructed on the basis of a validated food frequency questionnaire (FFQ) adapted to fruit and vegetable intake used for children (Huybrechts, De Bacquer, Matthys, De Backer, & De Henauw, 2006). The appendix shows the covariates included in the analysis.

2.6.2. Actual choice

When the children had finished both the pictorial and the questionnaire parts on the computers they were presented with a real product choice of eight smoothies. The test of children’s actual product choice was performed individually, and it took place outside the room to ensure that none of the other children were able to see the food choice. The smoothies were identical to those the children had seen on the computer screen previously. They were arranged in transparent glasses placed on a table with a white table cloth. The explanation given to the children was presented by a trained instructor by saying “You are looking at eight different smoothies. Which do you prefer the most?” The children had to point to the smoothie they preferred the most, and their real choice data were registered. The presentation orders of the different smoothies were randomised between the children, and all products were assigned a random 3-digit number.

2.6.3. Calculation of BMI

Height and body weight were determined without shoes to calculate BMI (kg/m²) and BMI z-scores. Height was measured on a Leicester portable height measure (Medisave, UK), and weight was registered on an ADE (M30014) Electronic Floor Scale (ADE GmbH & Co., Germany). BMI z-scores were calculated using British reference percentiles.

2.7. Data analysis

For each child, the ranks of the 8 pictures were scored in such a way that the first choice, i.e. the most preferred, was assigned a value of +2, the second choice was assigned +1, the least preferred was assigned −1 and the products not chosen were assigned 0 (Markussen, 2008; Reisfelt et al., 2009). For each child, the eight responses make up a 2³ layout, the with-in subject layout. Furthermore, the children were divided into eight groups formed by 2 (grade) × 2 (rural–urban) × 2 (time of visit), the between subjects layout. The total data set was analysed as a split plot layout, also called fixed effect analysis, with subjects as fixed effect, which makes all main effects and interactions of the with-in subject factors estimable. For the between subjects factors, the main effects are not estimable, however, the interesting effects are the synergistic effects between the food appearance factors and the segmentation factors. The synergistic effects are the interactions between the various factors. Due to the way of scoring, the mean product score for each subject is 0.25 which indicates that the main effects are not estimable. However, the fixed subject factor is included into the analysis, ANOVA, to obtain the correct number of degrees of freedom. Background variables are between subjects covariates and are included into the analysis as interactions with food appearance factors and segmentation factors.

Statistical analyses were performed using PASW Statistics, IBM Corporation, Route 100, Sommers, NY 10589.

3. Results

3.1. Children’s visual preferences

The overall results from the incomplete ranking test are shown in Fig. 2. The figures represent visual preference data for all children for both yoghurt and smoothie as means of all data. The data show that on average the children significantly preferred the large, dark portion of yoghurt without visible fruit (101) (Fig. 2a). The yoghurt preferred the second most was the small, dark portion of yoghurt without visible fruit (100). Thus, the two most preferred yoghurts were dark red and contained no visible fruit. The yoghurt preferred the least was the large, light red yoghurt with visible fruit (011), which was preferred significantly less than all the other yoghurts. Additionally, some significant differences were seen between the other five yoghurts. Fig. 2b also illustrates that children on average had a significantly higher preference for the large, light red smoothie without visible fruit (001) compared to the other smoothies, and this difference was very dominant. The second most preferred smoothie on average was the small, light red smoothie without visible fruit (000), and the preference for this smoothie was significantly different from the other smoothies as well. Summing up, the two most preferred smoothies were light red and without visible fruit. The large, dark red smoothie with visible fruit (111) was on average preferred least. The preferences for the five smoothies between the second most and the least preferred smoothie were also different from each other, except for the preference for smoothie 010 and 011.

3.2. Food appearance factors affecting visual preferences

In order to study the statistical effect of the two levels of the food appearance factors that may be drivers of children’s visual preferences for yoghurts and smoothies, a 3-way ANOVA was performed on both products (Table 4). As the fractional layout was balanced it allowed a unique decomposition of the total (with-in) subject variation into the sources of variation, i.e. 3 main effects, 3 first order interactions and one second order interaction. Also, it allowed the computation of the percentage allocation of the explained variation related the sources of variation.

For yoghurt, the food appearance factors ‘colour’ and ‘visible fruit’ and the synergistic effect between ‘visible fruit’ × ‘portion size’ contribute significantly to the explanation of the yoghurt model (p < 0.001). For the smoothie case, all food appearance factors contribute to the model (p < 0.001).

As regards both yoghurts and smoothies, the food appearance factor ‘visible fruit’ explains a dominant part of the variation as it accounts for 75% and 52%, respectively. This indicates that ‘visible fruit’ in both products is a vital factor. To determine which level of each food appearance factor drives children’s visual preferences the marginal means and the ‘contrasts’ between the means were calculated. Due to the design and the way of scoring, each contrast can assume values between −1 and +1, representing the estimated effect of absence (‘0’) and presence (‘1’) of the food appearance factors. The contrast represents children’s preferences of the corresponding product. A contrast close to 1 indicates preference for the specific food appearance factor being present, whereas contrasts close to −1 indicate preference for that specific food appearance factor being absent (Table 5). For the food appearance factor ‘visible fruit’ a contrast of −0.50 and −0.74 respectively, in favour of ‘without visible fruit’, indicates that children have a dominant high visual preference for both yoghurt and smoothie without visible fruit (Table 5). The food appearance factor ‘Colour’ explains a minor part of the variation in both the yoghurt and the smoothie model (17% and 27%), demonstrating that colour of the products explains less of the variation than ‘visual fruit’ (Table 4). As regards yoghurts, Table 5 shows a minor marginal contrast (0.24) in favour of ‘dark red’, illustrating a higher visual preference for the dark red yoghurt compared to the light red yoghurt. In contrast, children visually prefer the light red smoothie over the dark red smoothie shown by a relatively large contrast (−0.54) in favour of light red. The food appearance factor ‘portion size’ influences children’s
Finally, a synergetic effect between ‘colour’ and ‘portion size’ was seen for smoothie (Table 6). The children visually preferred the large, light red smoothie (marginal mean = 0.73). If the smoothie was dark red, the visual preference decreased (marginal mean = 0.03), and it decreased even further, if it was a large portion (marginal mean = −0.07).

To investigate children’s choice consistency, their first and second choice (the most and second most preferred) of smoothies were examined (Fig. 2). Two hundred and twenty-five (83%) of the children chose a smoothie without visible fruit as their most preferred product, and 238 children (88%) chose a smoothie without visible fruit as their second most preferred. This choice consistency was also seen for ‘colour’ and ‘portion size’, but was not as dominant. The tendency was also seen for yoghurt, but not to the same extent as for smoothie (data not shown).

### 3.3. Segmentation factors affecting visual preferences

The design of the study included the three food appearance factors discussed above and furthermore three segmentation factors segmenting children into ‘grade’, ‘urban/rural’ affiliation and ‘time of visit’ (Table 7). An additional decomposition of the sources of variation in Table 4 was performed by the between subject factors, i.e. segmentation factors, however, this decomposition was not unique. It is remarkable how small a contribution the segmentation factors make to the explanation of the variation. This means that most of the between subject variation remains unexplained. Significant synergetic effects between segmentation factors and food appearance factors for yoghurt were observed but not effect of segmentation factors on food appearance factors for smoothies.
was seen. No synergetic effect between the food appearance factor 'portion size' and any of the segmentation factors was seen.

Table 7 shows that there is a synergetic effect between the food appearance factor 'colour' and the segmentation factor 'urban/rural'. The calculated marginal means (Table 8) show that children in general prefer the dark red yoghurt. However, if the colour of the yoghurt is changed to light red, the contrast between the marginal means increases to a higher extent among urban children (contrast = 0.36) compared to the rural children (contrast = 0.16), indicating that the urban children are more sensitive to colour changes.

A synergetic effect was also seen between the food appearance factor 'colour' and the segmentation factor 'time of visit'. Children visited before lunch are more sensitive to changes in colour (contrast = 0.34) than children visited after lunch (contrast = 0.16). Table 7 also shows a synergetic effect between the food appearance factor 'visible fruit' and the segmentation factor 'time of visit'. Children visited before lunch had higher preferences for yoghurt without visible fruit compared to children visited after lunch as shown by a larger contrast (–0.58 and –0.40, respectively) (Table 8).

A synergetic effect between the food appearance factor 'colour' and the segmentation factor 'grade' shows that children in both 3rd and 6th grade prefer the dark red yoghurt. When the colour of the yoghurt is changed to light red, the contrast between the means increases to a higher extent for children in the 6th grade (contrast = 0.30) compared to children in the 3rd grade (contrast = 0.10) (Table 8).

3.4. Effect of background variables on visual choices

The statistical analysis shows that there are some effects of background variables on visual preferences for the two products. Significant effects were observed for gender and ethnicity. Gender shows a synergetic effect with the food appearance factor 'colour' of smoothies (p = 0.005) on visual preferences. Both genders prefer the light red smoothie, but boys preferred the dark red smoothie more than girls. This gender effect was not seen for yoghurt.

Ethnicity, expressed by the variables “Were you born in Denmark” and “Were your parents born in Denmark?”, interacts with the food appearance factors ‘colour’ and ‘visible fruit’ (p < 0.05). Children with different ethnic background/children with parents born elsewhere preferred the dark red smoothie and smoothies with visible fruit more than ethnically Danish children/children born of Danish parents. This was also observed for yoghurt (p < 0.001).

Additionally, a one way ANOVA showed a synergetic effect between the covariate hunger status and the segmentation factor ‘time of visit’ (p < 0.001).

3.5. Visual preferences in the picture-based conjoint layout versus actual choice

The reliability of children’s visual preferences determined by the picture-based conjoint layout was examined by correlating the results to data from the actual choice of the food products (Table 9). When emphasising the appearance factor ‘visible fruit’, 88.1% of the children chose the same level of visible fruit in the two tests and the Gamma’s correlation coefficient (r = 0.82, p = 0.002) elucidates a high correlation between the two tests (Table 9). In the conjoint layout, 238 children chose a smoothie

<table>
<thead>
<tr>
<th>Factors</th>
<th>Yoghurt</th>
<th>Smoothie</th>
<th>DF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total model</td>
<td>196.61</td>
<td>581.58</td>
<td>262/296</td>
</tr>
<tr>
<td>Colour</td>
<td>31.79</td>
<td>151.44</td>
<td>1</td>
</tr>
<tr>
<td>Visible fruit</td>
<td>117.62</td>
<td>292.04</td>
<td>1</td>
</tr>
<tr>
<td>Portion size</td>
<td>.36</td>
<td>12.94</td>
<td>1</td>
</tr>
<tr>
<td>Colour × visible fruit</td>
<td>.00</td>
<td>.00</td>
<td>1</td>
</tr>
<tr>
<td>Colour × portion size</td>
<td>.16</td>
<td>35.40</td>
<td>1</td>
</tr>
<tr>
<td>Visible fruit × portion size</td>
<td>12.38</td>
<td>65.70</td>
<td>1</td>
</tr>
<tr>
<td>Colour × visible fruit × portion size</td>
<td>.01</td>
<td>2.15</td>
<td>1</td>
</tr>
<tr>
<td>Colour × urban/rural</td>
<td>5.05</td>
<td>.05</td>
<td>1</td>
</tr>
<tr>
<td>Colour × time_of_visit</td>
<td>4.43</td>
<td>.07</td>
<td>1</td>
</tr>
<tr>
<td>Visible fruit × urban/rural</td>
<td>1.70</td>
<td>1.55</td>
<td>1</td>
</tr>
<tr>
<td>Visible fruit × time_of_visit</td>
<td>4.47</td>
<td>.14</td>
<td>1</td>
</tr>
<tr>
<td>Portion size × urban/rural</td>
<td>.28</td>
<td>.11</td>
<td>1</td>
</tr>
<tr>
<td>Portion size × time_of_visit</td>
<td>.38</td>
<td>.17</td>
<td>1</td>
</tr>
<tr>
<td>Colour × grade</td>
<td>10.88</td>
<td>1.10</td>
<td>1</td>
</tr>
<tr>
<td>Visible fruit × grade</td>
<td>1.76</td>
<td>.09</td>
<td>1</td>
</tr>
<tr>
<td>Portion size × grade</td>
<td>.83</td>
<td>.09</td>
<td>1</td>
</tr>
<tr>
<td>Children</td>
<td>.00</td>
<td>1.00</td>
<td>248/265</td>
</tr>
<tr>
<td>Error</td>
<td>1190.76</td>
<td>902.56</td>
<td>1748/1867</td>
</tr>
<tr>
<td>Total</td>
<td>1386.00</td>
<td>1479.50</td>
<td>2015/2151</td>
</tr>
</tbody>
</table>

Yoghurt $R^2 = 0.14$, Smoothie $R^2 = 0.39$.

SSQ = sum of squares. The segmentation factors and corresponding levels: Factors: Grade: 0 = 3rd grade and 1 = 6th grade, Urban/rural: 0 = urban and 1 = rural, time: 0 = before lunch and 1 = after lunch. The different values in the row 'children', 'Error and 'Corrected total' in the column 'DF' are caused by different number of children in the incomplete ranking of both yoghurt and smoothies. $R^2$ is the explained variation for the whole model. Significant $P$ values are bolded ($P < 0.05$).
without visible fruit while 226 children chose that in the actual choice test (data not shown). Similarly, a high correlation was seen according to portion size between the two choice tests ($r = 0.73$, $p = 0.000$) where 76.2% of the children chose the same level of portion size. Oppositely, a low correlation was observed between choices of colour between the two tests ($r = 0.38$, $p = 0.017$) where 65.4% of the children choose the same colour of smoothie. Two hundred and nineteen children chose the light red smoothie as their most preferred in the conjoint layout, whereas only 151 children chose the light red smoothie in the actual choice test (data not shown). These results correspond to the importance of each of the food appearance factors shown in Table 4. Furthermore, the results show that 135 children (50.2%) choose the same smoothie, regardless of the food appearance factors from the conjoint layout, in the two choice tests.

4. Discussion

The large difference in mean ranking scores between the most preferred yoghurt and the most preferred smoothie presented in Fig. 2 can probably be ascribed to the fact that children are more familiarised with yoghurt than smoothie. Smoothie is a relatively new food product in the Danish market, whereas yoghurt is highly embedded in the Danish culture. Children have different memories and frame of references of how yoghurt should appear, which causes different choices between the yoghurts. Having no memories could imply that children feel less confident in the product choice resulting in a search for something well-known on which to base the choice (the light red smoothie looks like red lemonade). This underlines the importance of a certain degree of familiarity to the products evaluated to assure that the food choices are based on children’s visual preferences, rather than lack of familiarity (Birch, 1979; Jaramillo et al., 2006).

In this study, both yoghurts and smoothies were designed to vary in the degree of novelty and complexity according to the level of the three food appearance factors. The food appearance factor ‘colour’ represents a level of novelty as traditional yoghurt in Denmark typically is light red. The food appearance factor ‘visible fruit’ represents complexity as a high amount of visible fruit in both smoothie and yoghurt increases the degree of complexity of the products. This indicates that products coded 000 were less novel and complex whereas products coded 111 were highest in novelty and complexity. Previous Reverdy, Schlich, Koster, Ginon, and Lange (2010) have shown that products low in complexity were closest to the children’s individual optimal arousal level, a concept introduced by Berlyne (Berlyne, 1960) and Dember and Earl (Dember & Earl, 1957). In this theory the arousal level of a stimulus is defined as a combination of novelty, complexity and intensity, and it determines the degree of liking. Based on that, a high preference for the light red yoghurt without visible fruit was expected due to the low level of novelty and complexity. Moreover, it is the most representative yoghurt on the Danish marked causing high familiarity. However, children preferred the large, dark red yoghurt without visible fruit (101). This disagreement supports the suggestion that segments of children have different visual preferences for yoghurt, causing the lower mean ranking score for yoghurt. These differences were not seen in relation to smoothie, where almost all children agreed that the large, light red smoothie without visible fruit (101) was the most preferred. The large, light red smoothie without visible fruit (001) was the least complex and most familiar product, and a high preference for this product was expected. On the other hand, it cannot be excluded that the colours presented on the computer screens were different from the colours of the real products. We acknowledge that the children may find the colours of the light red yoghurt on the computer screen less appealing compared to light red colour of the real yoghurt product which may have caused the high visual preference for dark yoghurt.

The effects of the various food appearance factors on children’s visual preferences are shown to be different, depending on both product and the food appearance factors. However, the food appearance factor ‘visible fruit’ is shown to have a very high impact on children’s preferences as regards both the smoothies and yoghurts (Table 5 and Fig. 2). One explanation could be that the presence of ‘visible fruit’ is too novel based on a visual input alone. If the children had had the possibility to taste the products during the test the novel product might be acceptable as long as the flavour was familiar. However, taste experience was not a part of this study, but the authors recommend to include taste experiences in future studies for comparison of visual and taste preference.

### Table 8
Synergetic effect between segmentation factors and two food appearance factors in yoghurt.

<table>
<thead>
<tr>
<th>Segmentation factors</th>
<th>Colour</th>
<th>Visible fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Levels</td>
<td></td>
</tr>
<tr>
<td>Urban/rural</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time of visit</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A positive marginal mean denotes that a factor = 1 is preferred more than the corresponding factor = 0, whereas a negative marginal mean denotes the opposite. The contrast is the difference between two marginal means level 0 minus level 1 and denotes if presence/absence of a food appearance factor increases or decreases children’s visual preferences.

- Not included as not statistical significant.

### Table 9
Correlation between choices in the picture-based conjoint layout and actual choice test.

<table>
<thead>
<tr>
<th>Food appearance factors</th>
<th>Same level (%)</th>
<th>Same level (%)</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colour</td>
<td>176</td>
<td>65.4</td>
<td>0.38</td>
<td>0.017</td>
</tr>
<tr>
<td>Visible fruit</td>
<td>237</td>
<td>88.1</td>
<td>0.82</td>
<td>0.002</td>
</tr>
<tr>
<td>Portion size</td>
<td>205</td>
<td>76.2</td>
<td>0.73</td>
<td>0.000</td>
</tr>
</tbody>
</table>

The non-parametric Gamma coefficients are calculated. Significant p-values are bolded (P < 0.05).
To the authors knowledge, no one else has studied the effect of visible fruit in yoghurt related to children's preferences, but Kalviainen, Roininen, and Tuorila (2003) found that young adults (20–35 years old) preferred yoghurt with a smooth texture over the lumpy one. However, in new product development of more healthy foods for children, e.g. by adding more fruit, it is essential for the food industries to know that children prefer no visible fruit in the foods. Such information can be obtained by applying the picture-based conjoint layout. The results of the present study clearly illustrate that the choice-based computer programme is highly suitable for evaluating children's visual preferences and thereby estimating the drivers of children's food choice. Yet, it is important to be aware of the fact that exposure to visual stimuli does not change children's preferences and thereby food choices. Taste preferences can be changed during repeated exposure to a taste stimuli whereby disliking is transformed into liking or oppositely.

When adding the segmentation factors to the model, an increase in R² from 0.12 (Table 5) to 0.14 (Table 7) is observed for yoghurt. This indicates that the model including the segmentation factors explains more of the variation than the model without these factors. Regarding the smoothies, R² does not change when the segmentation factors are included illustrating that addition of these factors do not increase the degree of explanation of the variation. Many synergetic effects were observed between food appearance factors and segmentation factors in the case of yoghurt, indicating that children's visual preferences and food choices to a high degree vary among children depending on grade, geographic affiliation and time of day (hunger status). Observation of differences in visual preferences between the urban and rural children signifies that geographical differences among children are an important factor in the evaluation of visual preferences. Socio-economic differences are also correlated with visual preferences of adult consumers (Gamble et al., 2006). Reisfelt et al. (2009) explored the effects of various background variables on visual preference of photos of five meal components and found that geographic variables, type of supermarket and level of education influenced visual preferences.

The synergetic effects between the segmentation factor 'time of visit' and the food appearance factors 'colour' and 'visible fruits' indicate that the state of hunger has an influence on children's visual preferences. Children who are hungry visually prefer the very smooth yoghurt and smoothie. The results showed that children visually preferred yoghurts and smoothies without visible fruit. Furthermore the results confirmed that the colours of the food products have a relatively high impact on visual preferences.

Also the segmentation factors, 'grade', 'urban/rural' affiliation and 'time of visit', had a significant effect on segmentation of children with different visual preferences. These are very important to be aware of in the development of new healthier food products for children. Additionally, the background variables gender and ethnicity influenced visual preferences to a minor, but significant degree.

A high correlation between the conjoint layout and actual product choices was found, indicating that the picture-based conjoint analysis is a powerful method that can be used as a fast and reliable evaluation of children's visual preferences.

**Conflict of interest**

The authors declare no conflicts of interests.

**Acknowledgement**

We acknowledge Jakob Lund Laugesen for developing the computer programme, Jens Michael Madsen for taking the photographs, as well as the companies Arla Foods amba. and Rynkeby Foods A/S for their assistance in developing and supplying the yoghurt and smoothie products. The Danish Agency for Science, Technology and Innovation is greatly acknowledged for financial support (FaSu-project: Step-by-step change of children's preferences towards healthier foods, J.nr. 3304-FSE-06-0504).

**Appendix**

The questionnarie.

<table>
<thead>
<tr>
<th>Questions posed</th>
<th>Response options</th>
<th>Assigned values</th>
</tr>
</thead>
<tbody>
<tr>
<td>How hungry are you right now?</td>
<td>I am not hungry</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>I am a little bit hungry</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>I am very hungry</td>
<td>3</td>
</tr>
<tr>
<td>Are you a female or a male?</td>
<td>Female, male</td>
<td>0,1</td>
</tr>
</tbody>
</table>
Appendix (continued)

<table>
<thead>
<tr>
<th>Questions posed</th>
<th>Response options</th>
<th>Assigned values</th>
</tr>
</thead>
<tbody>
<tr>
<td>How old are you?</td>
<td>8,9,10,11,12,13,14</td>
<td>8,9,10,11,12,13,14</td>
</tr>
<tr>
<td>Were you born in Denmark?</td>
<td>No, Yes</td>
<td>0,1</td>
</tr>
<tr>
<td>Were your parents born in Denmark?</td>
<td>No, they were</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Yes, they are</td>
<td>1</td>
</tr>
<tr>
<td>How often do you eat yoghurt?</td>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Seldom</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Almost every day</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Every day</td>
<td>5</td>
</tr>
<tr>
<td>How much do you like yoghurt?</td>
<td>I do not like it</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>at all</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I do not like it</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>I think it is ok</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>I like it</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>I like it a lot</td>
<td>5</td>
</tr>
<tr>
<td>How often do you drink smoothie?</td>
<td>Never</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Seldom</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Sometimes</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Almost every day</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Every day</td>
<td>5</td>
</tr>
<tr>
<td>How much do you like smoothie?</td>
<td>I do not like it</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>at all</td>
<td></td>
</tr>
<tr>
<td></td>
<td>I do not like it</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>I think it is ok</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>I like it</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>I like it a lot</td>
<td>5</td>
</tr>
</tbody>
</table>

The questionnaire with the questions posed and the response options. Additionally, values assigned to the response options after completing the study are added.

References

Abstract: Complexity is a fascinating phenomenon for food product developers and food scientists alike as a bell shaped relationship between liking and perceived complexity have been found by Berlyne (1971). However, to be able to actively use complexity in product development more knowledge about designed versus perceived complexity in real food systems is needed. Twenty four pictures of vegetable mixes, fruit mixes, and fruit & vegetable mixes varying in designed complexity by varying the cut, color, number of products, type of product, and combination of products was evaluated for perceived complexity by a descriptive panel. Additionally, the visual preferences of 119 adults (>16 years old) and 242 adolescents (10-16 years old) for the same pictures were measured by incomplete ranking. The results show high correlations between designed complexity and perceived complexity. Additionally, the designed complexity was found to have an effect on the adults’ and adolescents' visual preferences. Especially complexity design factors such as color and addition of uncommon products had an effect whereas the product size and geometric cut did not. The bell shaped curve could however not be proven for all mixes in this study and other factors besides complexity such as reported liking for the products in the mixes seems to have an effect on visual preference especially for the adolescents. Additionally, it was found that the adolescents had a lower optimal complexity level than did the adults.
Dear Editor

Enclosed is a paper, entitled” Complexity’s Effect on Adolescents’ and Adults’ Visual Preferences for Pictures of Fruit and Vegetable Mixes”. Please accept it as a candidate for publication in *Food Quality and Preference*.

Corresponding author of the attached manuscript is: Line Holler Mielby

Contact address:
Aarhus University, Department of Food Science
Kirstinebjergvej 10
DK-5792 Aarslev
Tel.: +4589993413
Fax: +4589993405
Email: LineH.Mielby@agrsci.dk

I look forward to hearing from you.

Yours sincerely,
Line Holler Mielby
Highlights

- High correlation between designed complexity and perceived complexity was found for pictures of fruit and vegetables.
- Color and addition of uncommon products had an effect on visual preferences for the fruit and vegetable mixes.
- The bell shaped relationship between liking and perceived complexity could not be proven for all mixes.
- Adolescents had a lower level of optimal complexity compared to the adults.
- Reported liking for the products in the mixes affected preference especially for the adolescents.
Complexity’s Effect on Adolescents’ and Adults’ Visual preferences for Pictures of Fruit and Vegetable Mixes

Line Holler Mielby¹*, Heidi Kildegaard¹, Gorm Gabrielsen², Merete Edelenbos¹, Anette Kistrup Thybo¹

¹Department of Food Science, Faculty of Science and Technology, Aarhus University, Kirstinebjergvej 10, DK-5792 Aarslev, Denmark

²Department of Finance, Centre for Statistics, Copenhagen Business School, Solbjerg Plads 3, DK-2000 Frederiksberg, Denmark

Corresponding author: Tel.: +45 89993413. Fax: +45 89993405. Email: LineH.Mielby@agrsci.dk

Abstract

Complexity is a fascinating phenomenon for food product developers and food scientists alike as a bell shaped relationship between liking and perceived complexity have been found by Berlyne (1971). However, to be able to actively use complexity in product development more knowledge about designed versus perceived complexity in real food systems is needed. Twenty four pictures of vegetable mixes, fruit mixes, and fruit & vegetable mixes varying in designed complexity by varying the cut, color, number of products, type of product, and combination of products was evaluated for perceived complexity by a descriptive panel. Additionally, the visual preferences of 119 adults (>16 years old) and 242 adolescents (10-16 years old) for the same pictures were measured by incomplete ranking. The results show high correlations between designed complexity and perceived complexity. Additionally, the designed complexity was found to have an effect on the adults’ and adolescents’ visual preferences. Especially complexity design factors such as color and addition of uncommon products had an effect whereas the product size and geometric cut did not. The bell shaped curve could however not be proven for all mixes in this study and other factors
besides complexity such as reported liking for the products in the mixes seems to have an effect on visual preference especially for the adolescents. Additionally, it was found that the adolescents had a lower optimal complexity level than did the adults.

**Keywords:** Designed and perceived complexity, adolescents and adults, pictures, fruit and vegetables, visual preferences

### 1 Introduction

Many factors besides the flavor of a food contribute to its liking (Zellner, 2007). The visual appearance is usually the first sensory stimuli that are presented to a consumer and which raises the expectations towards the food. The perceived properties may produce positive sensations leading to acceptance of a food, or negative sensations leading to rejection. Hence, visual cues and appearance are essential regarding acceptance or rejection of food (Cardello, 1996; Hurling & Shepherd, 2003). Appearance properties comprise various visual properties, including color, physical form and shape, and mode of presentation (Hurling and Shepherd, 2003).

In line with other commodities we can discuss the visual aesthetics of a food product and how to make the product more visual appealing and positively affect food choice. General principles and guidelines within design do exist such as, similarity, symmetry, order, balance and color (Hekkert & Leder, 2008). According to Berlyne’s collative motivation model (Figure 1), based on visual illustrations, patterns are preferred for their ability to generate arousal (Berlyne, 1971). Collative properties such as complexity, intensity, variety and novelty contribute most to the arousal potential (Berlyne, 1971).
Visual patterns with low arousal potential and thus low perceived complexity are not stimulating and leave the observer indifferent; patterns with very high arousal potential and high perceived complexity are too difficult to grasp and are considered unpleasant. Preferred are patterns with an arousal potential at a medium (or optimum) level, leading to the famous prediction of the inverted u-shaped function between hedonic tone (here liking) and arousal potential. Other important factors are familiarity. Familiarity and repetition makes perceptual and cognitive processing easier and somehow more fluent, and this fluency is intrinsically pleasant (Reber, 2004). The more fluent perceivers can process an object, the more positive their aesthetic response will be as indicated by the dotted curve in Figure 1. Zajonc provided a systematic empirical study of this phenomenon, reporting evidence that mere exposure to a stimulus increases its aesthetic appreciation (Zajonc, 1968). The study of complexity’s effect on subjects perception have been extended to other than visual artistic stimuli including perception of the aroma and perfumes (Jellinek & Köster, 1979; Jellinek & Köster, 1983; Sulmont, Issanchou, & Köster, 2002) and the overall perception of food products with special focus on mere exposure (Levy, MacRae, & Koster, 2006; Reverdy, Schlich, Köster, Ginon, & Lange, 2010; Sulmont-Rosse, Chabanet, Issanchou, & Köster, 2008). Only few studies have looked on the complexity of the visual stimuli of foods (Kildegaard, Olsen, Gabrielsen, Moller, & Thybo, 2011; Zellner, Lankford, Ambrose, & Locher, 2010). This is, however, not without problems as our perception of the appearance of food is affected by how we perceive its overall sensory quality, contrary to drawings which as such does not have a practical purpose. Nevertheless, if we want to use the principles of perceived complexity in product development we need to test the effect of changes in complexity on preference in real food systems. This also includes the visual complexity, especially due to the importance of the appearance on food choice.
Fresh fruit and vegetables are characterized by their varied appearance and bright colors. The shape, size, gloss, and vibrant color of fresh fruit and vegetables attract us and entice us into picking it up by fork or hand (Barret, Beaulieu, & Shewfelt, 2010). To study the effect of visual complexity of real food systems these particular food categories thus seem highly relevant as many visually very different mixes can be created. Taking the existing literature into consideration it is hypothesized that for fruit and vegetable mixes there is an optimal level of visual complexity. To be more specific, the following is hypothesized: ‘For mixes with a low level of designed complexity, preference will increase when increasing the level of designed complexity (Figure 1). For mixes with a medium level of designed complexity, visual preferences will find an optimum when increasing the designed complexity (Figure 1). For mixes with a high level of designed complexity, preference will decrease when increasing the designed complexity (Figure 1)’. All together, these hypotheses hereby seek to elucidate three parts of the complexity-liking relationship shown in Figure 1 with the underlying hypothesis that designed complexity is highly correlated with perceived complexity. Many factors affect preferences and it is thus additionally hypothesized that visual preferences for the fruit and vegetable mixes and hereby the level of designed complexity is affected by personal determinants such as age (adolescents vs. adults), with younger subjects being less exposed and thus prefers the less complex blends. This hypothesis is based on intuition as no studies have been published on this topic to the authors’ knowledge. Further, liking is commonly known to be important to food choice and it is thus hypothesized that liking of the products in the mixes is a factor to be taken into consideration.

The aims of this study are-to investigate the relationship between designed complexity and perceived complexity.
- to investigate if an effect of designed complexity on consumers visual preference of fruit and vegetable mixes exists, and whether this effect is bell shaped as predicted by Berlyne.

- to investigate the role of reported liking of the products in the mixes on visual preference for the fruit and vegetable mixes.

This paper will thus contribute to bringing us one step closer to actively use complexity in product development if complexity is proven to be an important factor for visual preferences for food such as fruit and vegetable mixes.

2 Methods

2.1 Pilot study

A pilot study was conducted prior to the current study. In this study, the role of portion size, skin color and cuttings’ effect on children and adolescents visual preference for apples was studied. The experimental design and the subjects are described by Kildegaard et al. (2011) and Figure A1 in the Appendix A shows the underlying design and visual stimuli used. The results showed significant differences in visual preferences for both portion size (small or large), color (red or red and green) and cut of apples (halves or squared) (Table A1 in Appendix A). Further significant interaction effects for portion size*color and portion size*cut of apples was found. In general, larger portion sizes and cut squared apples were preferred whereas mixed results were obtained for the color of apples. Based on these findings, the current study was designed.

2.2 Current study
2.2.1 Stimuli

Three sets of $2^3$ fruit, vegetable and fruit & vegetable mixes (24 mixes in total) were developed according to the designed complexity chart developed by the authors (Figure 2) and subsequently photographed. The designed complexity chart was developed based on the authors’ own perception of visual complexity.

The following parameters were considered important for the complexity design (from least complex to most complex): The cut, the amount of different colors and the contrast between the colors chosen, the amount of different products used, the product types and finally the combination of fruit and vegetables. The mixes were ranged according to their designed complexity and assigned a designed complexity score (D.C). To denote the designed complexity scores to the mixes, points for the presence of each parameter was given according to their level of complexity and subsequently summed. The points were given in different ranges to account for the differences in designed complexity i.e. differences in cut gave 1 ciphered points, differences in colors gave 2 ciphered points. Appendix B Table B1 shows the calculation of the designed complexity scores. All mixes weighed 175 gram, which was equally distributed between the number of products in the mix i.e. if a mix contained of 4 products each product weighed 44 g. The mixes were placed in 15 cm petri dishes without lids and photographed just after preparation. The pictures of the 24 mixes, their underlying design factors and their given designed complexity score (1= least complex 24=most complex) are displayed in Figure 3ab and c.

Figure 2

Figure 3ab and c
The fruit and vegetable mixes with the lowest level of designed complexity consisted of bell peppers in different colors (yellow, orange and red) and cuts (sticks $\frac{1}{2}$ by 8 cm vs. squares $\frac{1}{2}$ by 2 cm) (Figure 3a).

The fruit and vegetable mixes with the medium level of designed complexity were composed of apples in different cuts (1.5 cm x 5 cm long boats vs. 1.5 cm x 2 cm squares), different colored grapes (green and dark blue grapes) and presence of blueberries (Figure 3b). Apples and grapes were chosen as they are familiar and popular fruits in Denmark. Blueberries were chosen as these are a fairly new and uncommon commercial product on the Danish market, and it was relevant to see the effect of novelty on perception of fruit and vegetable mixes.

The fruit and vegetable mixes with the highest level of designed complexity consisted of both fruits and vegetable products (Figure 3c). This combination was hypothesized to be the most complex mixes of all, as it is, at least in Denmark, not common to mix these two groups together. In the fruit & vegetable mixes, bell peppers, either yellow or as a mix of yellow, orange and red were used as a base. Blueberries and grapes were chosen for the same reason as stated above whereas carrots were chosen as it is a very commonly consumed as a raw snack vegetable in Denmark.

2.2.1.1 The pictures

Pictures were taken of each mix with a Canon EOS 20D camera. The photos were taken at an aperture value of F20, at ISO 100, with a shutter speed of 1/200 sec, a focal length of 100 mm, and a resolution of 300*300 dpi in the sRGB color space. The photos were taken on a white uniform background and photo flash was used to ensure constant lighting conditions in the room.

2.2.2 Descriptive analysis of perceived complexity of the pictures of the fruit and vegetable mixes
To describe the objective perception of the pictures of the fruit and vegetable mixtures, a trained panel performed a descriptive analysis of the samples. The panel consisted of 10 subjects employed exclusively to work as assessors. Prior to the assessments, the panel went through two training sessions to select relevant sensory attributes. Each session lasted for two hours and included a subset of the sample set. The assessors developed a list of attributes for the pictures and agreed on a consensus list of attributes for the profiling and on the definition of each attribute including complexity. The assessors were unaware of the underlying complexity design in the study (Figure 2). During the attribute generation the assessors came up with the term complexity which they defined as ‘The more energy you spend to overview the picture the more complex it is’. Eight samples were assessed in the training session for the purpose of agreeing on the variation in attribute intensity. These eight samples spanned the variation within the sample set with regards to the attributes. The panelist evaluated the 24 samples in triplicate, during three sessions on three consecutive days. Samples were presented in a balanced order to account for sample order and carry-over effects (MacFie, Bratchell, Greenhoff, & Vallis, 1989). The panelists recorded their results on a 15-cm unstructured continuous scale with the left side of the scale corresponding to the lowest intensity and the right side corresponding to the highest intensity (Fizz software, 2.30 C, Biosystemes, Couternon, France). The panel evaluated 15 sensory attributes, but only the results from the complexity attribute will be reported here.

2.2.3 Consumer study design and procedure

The consumer study was performed in the same way for both adults and adolescents. A specialized computer program was used for the presentation of pictures and questionnaires. The program was written in MATLAB (MathWorks Inc., MA, USA), and installed on laptops (HP Elitebook 8530P) with 15.4 inches interfaces. The three sets of pictures vegetable (bell pepper) mixes, fruit mixes,
fruit & vegetables mixes) were evaluated on individual computers. The first computer displayed the pictures of the bell peppers, the second computer displayed the pictures of fruit and lastly the third computer displayed the pictures of the fruit & vegetable mixes. The computers therefore displayed the picture sets increasing in designed complexity. The computer program consisted of two separate parts; a pictorial part and a questionnaire part. The pictorial part was formed as a conjoint analysis, where all factor combinations were presented simultaneously. It was based on a full factorial design with the $2^3 = 8$ combinations of the pictures presented on the screen. The arrangement of the pictures on the computer screen was randomized for each consumer. The subjects made discrete choices by selecting their most, second most and least preferred choice, thereby performing an incomplete ranking of the eight mixes. When a picture was selected, the picture disappeared, and the remaining pictures on the screen changed their position in a randomized manner allowing the subjects to progress to the next choice. The questionnaire part included questions about the subjects’ age, gender and how much they like each products of the mixes (reported liking), bell peppers, apples, grapes, blueberries and carrots (seven point hedonic scale). To ensure independency between the picture and the questionnaire part, the questionnaire part was the last task in a test session.

2.2.3.1 Subjects participating in the consumer study

2.2.3.1.1 Adults

A total of 119 adults (16 years old and above) were recruited from a Danish supermarket in one of the largest malls in Denmark (Kvickly in Rosengaardscenteret, Odense) (Table 1). This mall draws consumers from a large area of Funen including Odense. All participating adults were given the opportunity to participate in a lottery for wine (2 wine packages with the value of 500 DKR each). The complete test procedure was pre-tested among adults at an Open University event.
2.2.3.1.2 Adolescents

A total of 242 adolescents (10-16 years old, in 5th, 7th and 9th grade) were recruited from 2 public schools in Jutland, Denmark (Table 1). Both schools were large public schools situated in the outskirts of two medium large cities (Vejen and Fredericia with 42,703 and 36,513 inhabitants, respectively). The participating adolescents came from the cities or from the surrounding country sides and were equally distributed between girls and boys. There was a majority of subjects from the 7th grades which is also illustrated in the age distribution (Table 1).

Table 1

The adolescents were recruited through a three-step procedure: 1) definition of recruiting criteria, 2) contact to the heads of the schools and/or teachers, and 3) contact to the adolescents and their parents. The adolescent and their parents had the opportunity to reject participation at any time. Previous research has used similar recruiting procedures (Nørgaard, 2009). Rooms adjacent to the subjects’ school classrooms were chosen as the place to conduct the tests. During the complete study, testing was distributed evenly between the lessons just before or after lunch. Each testing began with an introduction to the procedure of the test in the classrooms. Secondly, subjects were taken to the testing room two at a time to complete the test on the computers. Lastly, all subjects were gathered in the classroom and as a token of appreciation, they were provided a piece of fruit. The complete test procedure was pre-tested among adolescents in a 5th and a 7th grade class.

2.2.4 Data analysis

Mean values including 95% confidence intervals were calculated for the perceived complexity obtained from the descriptive analysis of the pictures. These values were correlated with the designed complexity.
With regards to the consumer testing the data analysis procedure was identical for the adults and the adolescent subjects. For each subject, the ranks of the 8 pictures were scored in such a way that the first choice, i.e. the most preferred, was assigned a value of +2, the second choice was assigned +1, the least preferred was assigned -1 and the products not chosen were assigned 0 (Kildegaard et al., 2011; Reisfelt, Gabrielsen, Aaslyng, Bjerre, & Møller, 2008). The two data sets (adults and adolescents) were analyzed by as fixed effect analysis, with subjects as fixed effect. An additional analysis was made with reported liking included as a covariate to test the effect of reported liking on visual preference for the fruit and vegetable mixes.

To test the effect of perceived complexity the scores of the 8 pictures including all subjects was regressed by OLS on the perceived complexity of the 8 pictures (being the same for all subjects). We included a term of second degree into the general linear model to estimate a possible maximum of the polynomium (the parabola).

Statistical analyses were performed using PASW Statistics 18, IBM Corporation, Route 100, Sommers, NY 10589.

3 Results

3.1 Relationship between designed and perceived complexity

The correlation between the designed complexity and the perceived complexity of the 24 pictures of fruit and vegetable mixes is displayed in Figure 4. The perceived complexity is based on the mean values across the 10 assessors.
The relationship is linear ($R^2=0.84$) indicating high correlation between designed and perceived complexity with a few exceptions. Sample FV000 seems to be an outlier and when removed $R^2$ increases to 0.92. This sample consisted of yellow bell peppers sticks and light green grapes and the reason this sample was evaluated low in complexity might be due to the low color contrast (picture shown in Figure 3c). The samples F000 and F001 (Figure 3b) did not display large color contrast either and they were also evaluated lower in perceived complexity compared to the regression line. With regards to the fruit mixes, the mixes which contained the uncommon blueberries (F_1_ in Figure 3b) were considered more complex compared to the fitted regression. The fact that there was such a good correlation between the perceived and designed complexity makes it feasible to look at the effect of the complexity design factors F1, 2 and 3 separately for all three sets of pictures bell pepper (V), fruit (F) and fruit and vegetable (FV) on both adults’ and adolescents’ visual preferences (Table 2).

### 3.2 Relationship between the designed complexity factors and visual preferences

Table 2 displays the results of the adults’ and adolescents’ visual preferences for the three sets of mixes with regards to the design factors F1, F2 and F3 (Figure 3 for design details).

#### Vegetable mixes

With regards to the pictures of bell pepper, color (F1 and F2) and cut (F3) as well as their interaction effects (F1*F2, F1*F3 and F2*F3) were significant for the adults, whereas only the color (F1 and F2) and the color interaction (F1*F2) were significant for the adolescents (Table 2a). Taking the level means into consideration as well, no large differences were found between adults’ and adolescents’ visual preferences for the pictures.
According to the color interaction effects, the adults and the adolescents preferred the color contrast full yellow and red bell pepper mix the most. This was followed by the designed most complex yellow, red and orange bell pepper mixes (V10_ and then V11_ Figure 3a) since these factor level combinations displayed the largest level means. The designed least complex yellow bell pepper mix (V00_ Figure 3a) was least preferred. For the adults, the cut (F3) and the corresponding interaction effects (F1*F3 and F2*F3) were also found significant. In general bell peppers cut in sticks were preferred over the cubes (V_ _0 Figure 3a). Sticks was according to the designed complexity chart (Figure 2) considered as the least complex cut.

**Fruit mixes**

For the fruit mixes which varied in color (F1), product types (F2) and cut (F3) different results were found for the adults and the adolescents (Table 2b). All main effects of color (F1), product types (F2) and cut (F3) as well as the interaction effect F1*F2 (color*product type) was significant for the adults whereas only the interaction effect F2*F3 (product type*cut) was significant for the adolescents. The adults preferred the fruit mixes with the most colors and uncommon product types (F11_ Figure 3b). Especially the addition of blueberries had a positive effect on the adults’ preference. The color-product type mix least preferred was the designed least complex mix containing only green grapes and apples (F1=0 and F2=0 Figure 3b). In general apples cut in slices (F_ _0 Figure 3b) were preferred by the adults. This cut was according to the designed complexity chart (Figure 2) considered as the least complex cut. The significant interaction effect F2*F3 (Table 2b) for the adolescents means that the adolescents preferred different cuts of the apples in the mix depending on the presence/absence of blueberries independent of the grapes in the mix. For the adolescents the most preferred combination was no blueberries and apples in slices (F_00 Figure
3b), second preferred was blueberries and apples in cubes (F_11 Figure 3b). The least preferred mix was blueberries and apples in slices (F_10 Figure 3b). The differences were however not that large. These results might be an indication of adolescents preferring mixes where the products are somewhat similar in size, rather than more or less complex mixes.

**Fruit & vegetable mixes**

Differences between the visual preferences of the adults and the adolescents were also found for the fruit and vegetable mixes (Table 2c). The main effects for color of bell pepper (F1), presence/absence of blueberries (F2) and grapes or carrots (F3) as well as the interaction effects F1*F2 (color*presence or absence of blueberries) and F2*F3 (presence/absence of blueberries*grapes or carrots) were found significant for the adults, whereas the factors F1, F3 and F1*F2 were significant for the adolescents. With regards to the interaction effect F1*F2 adults and adolescents agreed that multicolored bell peppers were preferred over simple yellow bell pepper (FV1_ _ over FV0_ _ Figure 3c) and while adults preferred this color full blend in combination with blueberries (FV1_ _ Figure 3c) the adolescents did not. If the blend only consisted of yellow bell peppers both adults as well as adolescents visually preferred the presence of blueberries (FV01_ _ Figure 3c). This could be an indication of a different effect of color variety on adults’ and adolescents’ visual preference rather than the presence of an uncommon product such as blueberries. For the adults the perception of presence/absence of blueberries was also affected by either having carrots or grapes in the mix. Green grapes were in general visually preferred compared to carrots especially in combination with blueberries (FV_ _0 Figure 3c). Blueberries and carrots was the visually least preferred mix (FV_ 11 Figure 3c).

### 3.3 Relationship between perceived complexity and visual preference
The high correlation between the designed and perceived complexity (Figure 4) and the significant effects of the designed complexity factors (F1, 2 and 3) for all three sets of mixes on the adults and the adolescents’ visual preferences (Table 2), made it feasible to test how well our data fitted the bell shaped curve theory of Berlyne (1971).

Figure 5 displays the relationship between perceived complexity and visual preference for adults and adolescents for the three sets of mixes. As can be seen the results for the bell pepper mixes and fruit mixes follow the theory of Berlyne (1971) whereas the fruit & vegetable mixes does not.

**Figure 5**

**Vegetable (bell pepper) mixes**

With regards to the bell pepper mixes the parable does as hypothesized increase for both the adults’ and the adolescents’ visual preferences. Further, it is seen that the parable seems to reach an optimal complexity level. The optimal level of complexity is reached faster for the adolescents compared to the adults.

**Fruit mixes**

The fitted parable for the fruit mixes for the adults and the adolescents’ visual preferences shows the top of the parable as hypothesized. Again it is seen that the optimal complexity level is reached faster for the adolescents compared to the adults. This is in agreement with the hypothesis that the longer exposure time for adults made them visually prefer more complex blends.

**Fruit & vegetable mixes**

With regards to the fruit & vegetable mixes the visual preferences does not decrease as hypothesized. The relationship is on the other hand increasing for both adults’ and adolescents’
visual preferences. This indicates that for the combination of fruit and vegetables other factors than complexity such as reported liking of the products of the mix might have an effect on the overall visual preference of the mixes.

Other factors effect on visual preferences of the designed complexity factors

To look at the effect of reported liking of the products of the mixes on adults and adolescents’ visual preferences of the mixes analyses with liking of the products added as covariates were calculated (Table 3ab and c).

Vegetable (bell pepper) mixes

When looking on the results from the bell pepper mixes it is seen that the adults’ and the adolescents’ visual preferences are affected by their reported liking of bell pepper (Table 3a). The more bell pepper were liked the more the yellow and red combination (V1_ _ Figure 3a) is visually preferred compared to the simpler yellow bell pepper mixes (V0 _ _ Figure 3a) for both adolescents and adults. This is seen by a significant effect of F1*bell pepper liking in Table 3a. The cut (F3*bell pepper liking) was also visually preferred differently according to the adults’ and adolescents’ liking of bell pepper, with sticks visually preferred if bell pepper was reportedly liked (V_ _0 Figure 3a).

Table 3

Fruit mixes

For the fruit mixes visual preferences was also affected by reported liking of either grapes and blueberries for both adults and adolescents however in different ways. Significant interaction effects
were found for adults with regards to color (F1*grape liking, F2*grape liking and F2*blueberry liking). If the adults reportedly liked grapes they visually preferred mixes with both green and blue grapes and blueberries more than if they did not like grapes (F11_ Figure 3b). The more they reportedly liked blueberries the more they visually preferred mixes with blueberries (F1_ Figure 3b).

For adolescents significant interaction effects were found for both reported liking and color and cut (F3*grape liking, F3*apple liking, F1*blueberry liking and F2*blueberry liking). The more the adolescents liked grapes the more they visually preferred the apples cut in cubes (F1_ Figure 3b) whereas the more they liked apples they visually preferred them cut in slices (F0 Figure 3b). The more adolescents liked blueberries the more they visually preferred them in the blend (F1_ Figure 3b) and the more they visually preferred a mix of both green and blue grapes (F1_ Figure 3b).

Fruit & vegetable mixes

For the fruit & vegetable mixes significant interaction effects were found for the adults between F2*grape liking, F3*grape liking and F2*blueberry liking. The more the adults reportedly liked grapes the more they visually preferred them in the mix (FV_ 0 Figure 3c) and the more they also visually preferred blueberries in the mix (FV_ Figure 3c). Blueberries were also more preferred in the mix if these were liked. The adolescents were more affected by their reported liking of individual products and significant differences were found between F3*grape liking, F1*bell pepper liking, F2*bell pepper liking, F3*bell pepper liking and F1*blueberry liking and F2* blueberry liking. If they reportedly liked grapes they visually preferred them in the mix (FV_ 0 Figure 3c). If they reportedly liked bell peppers they visually preferred a variety of colors of bell peppers (FV1_ Figure 3c), blueberries (FV_0_ Figure 3c) and carrots in the mix (FV_1 Figure 3c). If they
liked blueberries, they visually preferred these (FV_1_ Figure 3c) and only yellow peppers in the mix (FV0_ Figure 3c).

The above mentioned results clearly show that one should be aware of reported liking and other factors effect of preference (here visual preference) when wanting to study complexity. The effects of gender and age on the adults and adolescents’ visual preferences for the mixes varying in complexity have also been calculated. Due to the scope of this paper these results will however be presented elsewhere.

4 Discussion

One of the most critical points in conducting consumer studies focusing on complexity is the matter of designed versus perceived complexity and how this is measured if measured at all. The straight way of measuring perceived complexity is to ask the consumers directly how they perceive the complexity of a product as done in other studies (Jellinek and Köster, 1979; Sulmont et al., 2002; Sulmont-Rosse et al., 2008). To do this, it should be unambiguous that all consumers understand the concept “complexity”. This study looked into both adults and adolescents’ visual preferences for pictures of fruit and vegetable mixes varying in designed complexity. Our previous experience working with adolescents made us doubt that all adolescents knows the concept “complexity”. Therefore, we did not ask any of the subjects about their perceived complexity of the fruit and vegetable mixes. However, it was still found highly relevant to investigate the relationship between our designed complexity and complexity perceived by others. A measure for perceived complexity was thus obtained through a descriptive panel. This measurement was found to be the best alternative and an approximation towards adults’ and adolescents’ perception of complexity with the underlying assumption that people somewhat have the same perception of degree of complexity.
Other studies have also indirectly measured the perceived complexity by deducing it from other attributes found related to perceived complexity by for instance focus groups (Levy et al., 2006; Porcherot & Issanchou, 1998). In the current study, a high correlation between designed and perceived complexity was found for the mixes (Figure 4). This result strongly indicate that we all, in this case researcher and panel have some sort of common understanding of what seems complex and the degree of it. Especially when taking into consideration that the panel themselves and not the authors came up with their own definition of complexity. The high correlation is based on visual clearly different stimuli and future studies are needed to test whether this relationship and thus common understanding can be extended to other products as well. Further, it is highly relevant to test ways of directly testing perceived complexity with all consumer groups including adolescents instead of using a descriptive panel.

The high correlation between perceived and designed complexity, made it relevant to investigate the effect of the designed complexity factors for all mixes on adults’ and adolescents’ visual preferences. The designed complexity had an effect on both adults’ and adolescents’ visual preferences (Table 2). Adults’ visual preferences were affected by all complexity design factors cut, color, addition of uncommon product types and product combinations. Adolescents’ visual preferences were however only affected by color (F1 and 2) in the bell pepper set as well as in the fruit & vegetable set (F1), the presence of uncommon blueberries and cut of apples in the fruit case (F2*F3) and the addition of either grapes or carrots to the fruit & vegetable mix (F3). These results indicate that the designed complexity factors did have an effect on the adults’ and the adolescents’ visual preferences for the mixes but that other factor are affecting especially the adolescents’ visual preferences. When conducting the study the adults seemed to spend more time to look at the pictures and complete the test compared to the adolescents. This might have resulted in more considerate choices and thus larger effects of the design factors on visual preferences. The
completion time for each participant was however not recorded and it is thus difficult so conclude anything about the effect of processing time of each picture. Processing time have previously been found to have an effect on the perception of visual stimuli (Leder, Carbon, & Ripsas, 2006).

Further, when looking at the pictures, some of the adolescents immediately stated which of the products in the mixes they liked and this focus might have been stronger than some of the design factors.

It was the hypothesis that in general the visual preference for the bell pepper mixes should increase with perceived complexity, the visual preference for the fruit mixes should find an optimal complexity level while the visual preference for the fruit & vegetable mix should decrease with perceived complexity according to the theory of Berlyne (1971). The fitted relationships for the visual preference and the perceived complexity relationship were as hypothesized for the bell pepper and the fruit mixes but not for designed most complex fruit & vegetable mixes (Figure 5).

The pictures used in this study was of cut fruit and vegetables and one reason we did not see a decrease in preference for the most complex set of mixes might be, that the mixes simply were not complex enough and that the effect of reported liking was much greater than the perceived complexity as will be discussed below. Another reason for these results might be, that they are not on an individual level. As noted by Levy et al.(2006) it would have been the most correct to look at the relationship between perceived complexity and liking on an individual level since this relationship is based on individuals and individuals have their own level of optimal complexity.

This was however not possible due to the structure of the incomplete ranking data set. This study thus only made it possible to look more generally on the relationship. Other studies have however also had problems reporting evidence for the bell shaped relationship within food products (Porcherot and Issanchou, 1998). According to Hekkert and Leder, (2008) Berlyne himself also acknowledged limitations of his model when dealing with more naturalistic and daily life products.
compared to visual stimuli. This however, does not make perceived complexity less interesting as relationships between perceived complexity and preference was found.

As indicated by the adolescent’s statements when looking at the pictures the first time, reported liking of individual products might also affect visual preference for the different mixes. The models (Table 3) indicate that this is the case for all sets of mixes. Adults and adolescents seemed to be just as affected by reported liking of the products for the bell pepper and the fruit mixes, whereas adolescents were much more affected by their reported liking of the products in the complex fruit & vegetable mixes compared to the adults. Many of the effects of reported liking seem obvious, such as preferring mixes with grapes when liking grapes. Other relationships were not as obvious such as the relationship between liking of grapes and blueberries which interacted with the presence of each other. Many of the studies on complexity in food have studied stimuli where liking of the different stimuli is not as such an issue since the base products was the same such as lemonade (Levy et al., 2006). However, if wanting to use complexity in real food systems, differences in liking of the used products might very well be an issue and the above mentioned results stresses the importance of measuring the effect of reported liking, both the obvious as well as the not so obvious relationships.

The lower optimal level of complexity for the adolescents compared to the adults in addition to the larger effect of reported liking of products in the mixes certainly stresses this point and shows that results cannot be generalized across age groups, as different factors might have different effects.

The designed complexity chart which the samples of this study was based on was constructed based on the authors’ intuition. The least complex factor was cut which did not have much effect on the subjects’ visual preferences. The design factor color however seemed to have a great effect. The levels of this factor ranged from one to more colors, but it also seems that color contrast had a large effect as well. The correlation between the designed and the perceived complexity (Figure 4) showed that the least color contrast full pictures were below the tendency line whereas the color
contrast full samples were in general above the tendency line. In future studies color contrast might thus be interesting to study further in relationship with complexity.

5 Conclusion

This paper sought to contribute to bringing us one step closer to actively use complexity in product development if complexity was proven to be important for visual preferences for food products such as fruit and vegetable mixes.

A high correlation was found between designed and perceived complexity. This result suggests a common understanding of what is perceived more or less complex. This result makes it much more approachable to actively incorporate complexity into product development in the future, if precautions are taken to include all (most) factors thought to affect perceived complexity. However additional studies are needed to confirm these results under other conditions. The knowledge of complexity’s effects on preference for fruit and vegetable also extends the possibilities within product development, promotion and intake of these healthy foods.

Designed and perceived complexity was found to affect adults’ and adolescents’ visual preferences for fruit and vegetable mixes, however the bell shaped relationship proposed by Berlyne (1971) could not be confirmed for all sets of pictures. Additionally, it was found that the adolescents had a lower optimal complexity level than did the adults. This stresses the importance of not generalizing results across age groups with regards to preferences.

This paper also stresses the importance of investigating other factors besides complexity in studies on complexity such as initial reported liking of products in the studied food matrix. Differences in visual preferences were found according to the liking of the products especially for the adolescents.
Acknowledgements

We acknowledge Peter Quist and Jens Michael Madsen for taking the pictures. This work was undertaken in the COOL SNACKS research project, contract No 2101-08-0006. The financing of the work by the Danish Council for Strategic Research (DSF), the program committee for Health, Food and Biological Production is also gratefully acknowledged.

References


Figure 1: Berlynes (1971) reported relationship between perceived complexity and liking. Figure modified from Levy et al. (2006) including some of the visual presentations used by Berlyne (1966) to predict the relationship.

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
<table>
<thead>
<tr>
<th>Low Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cut</strong></td>
<td>More smaller pieces</td>
</tr>
<tr>
<td>One color</td>
<td>More colors (and then color contrast)</td>
</tr>
<tr>
<td>Few products</td>
<td>More products</td>
</tr>
<tr>
<td>Common products (in DK)</td>
<td>Less common products (in DK)</td>
</tr>
<tr>
<td>Only fruit or vegetables</td>
<td>Fruit and vegetables together</td>
</tr>
</tbody>
</table>

Figure 2: Designed complexity chart, going from lower to higher complexity both vertically and horizontally.

The chart is based on the authors’ own perception of complexity.

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
3a) Vegetables (bell pepper) mixes

<table>
<thead>
<tr>
<th>Design factor F1: Color</th>
<th>Design factor F2: Color</th>
<th>Design factor F3: Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow (F1=0)</td>
<td>Yellow and red (F1=1)</td>
<td></td>
</tr>
<tr>
<td>- Orange (F2=0)</td>
<td>+ Orange (F2=1)</td>
<td></td>
</tr>
<tr>
<td>Small cubes (F3=1)</td>
<td>Small cubes (F3=1)</td>
<td></td>
</tr>
<tr>
<td>Sticks (F3=0)</td>
<td>Sticks (F3=0)</td>
<td></td>
</tr>
<tr>
<td>Name of the mix</td>
<td>Name of the mix</td>
<td></td>
</tr>
<tr>
<td>V000</td>
<td>V001</td>
<td>D.C. 1</td>
</tr>
<tr>
<td>D.C. 2</td>
<td>D.C. 3</td>
<td></td>
</tr>
<tr>
<td>D.C. 4</td>
<td>D.C. 5</td>
<td></td>
</tr>
<tr>
<td>D.C. 6</td>
<td>D.C. 7</td>
<td></td>
</tr>
<tr>
<td>D.C. 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3 b) Fruit mixes

- Blueberries (F2=0)
  - Blueberries (F2=1)
    - Blueberries (F2=0)
      - Blueberries (F2=1)
        - Blueberries (F2=0)
          - Blueberries (F2=1)
            - Blueberries (F2=0)
              - Blueberries (F2=1)

Blue and green grapes (F1=1)

- Blueberries (F2=0)
  - Blueberries (F2=1)
    - Blueberries (F2=0)
      - Blueberries (F2=1)
        - Blueberries (F2=0)
          - Blueberries (F2=1)

Name of the mix

Design factor F1: Color
Design factor F2: Product types
Design factor F3: Cut
Figure 3ab and c: Design of the mixes including the design factors $F_1$, $F_2$ and $F_3$

and their levels and the pictures used in the study. The designed complexity score (D.C.)

(1=least complex, 24=most complex) is included to the far right.

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
Figure 4: Correlation between designed complexity and perceived complexity measured by descriptive analysis including standard error bars and letters indicating 95% confidence intervals.

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
Figure 5ab and c: Fitted relationship between perceived complexities measured by the descriptive panel and the adults and adolescents preferences for the three sets of mixes, bell pepper mixes, fruit mixes and fruit and vegetable mixes.

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
Table 1: Description of participating consumers, adults and adolescents

<table>
<thead>
<tr>
<th>Gender</th>
<th>Female</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults (n=119)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (n)</td>
<td>16-20 years</td>
<td>18</td>
</tr>
<tr>
<td>Gender</td>
<td>Female</td>
<td>70</td>
</tr>
</tbody>
</table>

| Adolescents (n=242) | | |
| Age (n) | 10 years | 1 | 11 years | 43 | 12 years | 49 | 13 years | 46 | 14 years | 32 | 15 years | 59 | 16 years | 12 |
| Gender | Female | 121 | Male | 121 |

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)

Table 2a, b and c: P-values and level means for preference of significant factors for vegetable mixes (a), fruit mixes (b) and fruit & vegetable mixes (c) for both adults and adolescents with regards to the design parameters F1, F2 and F3. Only significant P-values are given.
<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>b) Fruit mixes adults</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 Color</td>
<td>p&lt;0.005</td>
<td>F1 level 0: Green</td>
<td>.134</td>
<td>F1 Color</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Green and blue</td>
<td>.366</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2 Product types</td>
<td>p&lt;0.005</td>
<td>F2 level 0: No blueberries</td>
<td>.067</td>
<td>F2 Product types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.433</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3 Cut</td>
<td>p&lt;0.005</td>
<td>F3 level 0: Slices</td>
<td>.351</td>
<td>F3 Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 1: Cubes</td>
<td>.149</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 * F2 Color*product types</td>
<td>p&lt;0.005</td>
<td>F1 level 0: Green</td>
<td>F2 level 0: No blueberries</td>
<td>-.155</td>
<td>F1 * F2 Color*product types</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Green and blue</td>
<td>F2 level 1: Blueberries</td>
<td>.424</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 0: No blueberries</td>
<td>F2 level 1: Blueberries</td>
<td>.290</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.441</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 * F3 Color*cut</td>
<td>-</td>
<td>F1 level 0: Green</td>
<td>F3 level 0: Slices</td>
<td>.321</td>
<td>F1 * F3 Color*cut</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Green and blue</td>
<td>F3 level 1: Cubes</td>
<td>.149</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 0: Blueberries</td>
<td>F3 level 0: Slices</td>
<td>.351</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Blueberries</td>
<td>F3 level 1: Cubes</td>
<td>.149</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F2 * F3 Product types*Cut</td>
<td>-</td>
<td>F2 level 0: No blueberries</td>
<td>F2 level 1: Blueberries</td>
<td>.262</td>
<td>F2 * F3 Product types*Cut</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 0: Slices</td>
<td>F2 level 1: Cubes</td>
<td>.186</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Slices</td>
<td>.262</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Cubes</td>
<td>.262</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 0: Slices</td>
<td>.351</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 1: Cubes</td>
<td>.149</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>c) Fruit &amp; vegetable mixes adults</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 Color</td>
<td>p&lt;0.005</td>
<td>F1 level 0: Yellow</td>
<td>.074</td>
<td>F1 Color</td>
<td>p&lt;0.005</td>
<td>F1 level 0: Yellow</td>
<td>.117</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Yellow, red and orange</td>
<td>.426</td>
<td></td>
<td></td>
<td>F1 level 1: Yellow, red and orange</td>
<td>.383</td>
</tr>
<tr>
<td>F2 Product types</td>
<td>p&lt;0.005</td>
<td>F2 level 0: No blueberries</td>
<td>.172</td>
<td>F2 Product types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.328</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3 Product combin ations</td>
<td>p&lt;0.005</td>
<td>F3 level 0: Grapes</td>
<td>.351</td>
<td>F3 Product combin ations</td>
<td>p&lt;0.005</td>
<td>F3 level 0: Grapes</td>
<td>.446</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 1: Carrots</td>
<td>.149</td>
<td></td>
<td></td>
<td>F3 level 1: Carrots</td>
<td>.054</td>
</tr>
<tr>
<td>F1 * F2 Color*Product types</td>
<td>p=0.031</td>
<td>F1 level 0 Yellow</td>
<td>F2 level 0: No blueberries</td>
<td>-.063</td>
<td>F1 * F2 Color*Product types</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1 Yellow, red and orange</td>
<td>F2 level 1: Blueberries</td>
<td>.210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 0: No blueberries</td>
<td>F2 level 1: Blueberries</td>
<td>.408</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.445</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 * F3 Color*Product combinations</td>
<td>-</td>
<td>F1 level 0 Yellow</td>
<td>F3 level 0: Grapes</td>
<td>.063</td>
<td>F1 * F3 Color*Product combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1 Yellow, red and orange</td>
<td>F3 level 1: Carrots</td>
<td>.210</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 0: Grapes</td>
<td>F3 level 1: Carrots</td>
<td>.149</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
<th>Factors</th>
<th>p-value</th>
<th>Levels</th>
<th>Level means</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fruit &amp; vegetable mixes adolescents</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 Color</td>
<td></td>
<td>F1 level 0: Yellow</td>
<td>.117</td>
<td>F1 Color</td>
<td></td>
<td>F1 level 0: Yellow</td>
<td>.117</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1: Yellow, red and orange</td>
<td>.383</td>
<td></td>
<td></td>
<td>F1 level 1: Yellow, red and orange</td>
<td>.383</td>
</tr>
<tr>
<td>F2 Product types</td>
<td></td>
<td>F2 level 0: No blueberries</td>
<td>.194</td>
<td>F2 Product types</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.194</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F3 Product combin ations</td>
<td></td>
<td>F3 level 0: Grapes</td>
<td>.436</td>
<td>F3 Product combin ations</td>
<td></td>
<td>F3 level 0: Grapes</td>
<td>.436</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 1: Carrots</td>
<td>.331</td>
<td></td>
<td></td>
<td>F3 level 1: Carrots</td>
<td>.331</td>
</tr>
<tr>
<td>F1 * F2 Color*Product types</td>
<td></td>
<td>F1 level 0 Yellow</td>
<td>F2 level 0: No blueberries</td>
<td>.039</td>
<td>F1 * F2 Color*Product types</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1 Yellow, red and orange</td>
<td>F2 level 1: Blueberries</td>
<td>.194</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 0: No blueberries</td>
<td>F2 level 1: Blueberries</td>
<td>.436</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2 level 1: Blueberries</td>
<td>.331</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F1 * F3 Color*Product combinations</td>
<td>-</td>
<td>F1 level 0 Yellow</td>
<td>F3 level 0: Grapes</td>
<td>.039</td>
<td>F1 * F3 Color*Product combinations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1 level 1 Yellow, red and orange</td>
<td>F3 level 1: Carrots</td>
<td>.194</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3 level 0: Grapes</td>
<td>F3 level 1: Carrots</td>
<td>.331</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3a, b and c: P-values and parameter estimates for preference of significant design factors for vegetable mixes (a), fruit mixes (b) and fruit & vegetable mixes (c) for both adults and adolescents with regards to their interaction with reported liking of the products in the mixes. P-values for the design factors F1, F2 and F3 are not listed. Only significant P-values are given.

### a) Vegetable mixes (bell pepper) adults

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color*Bell pepper liking</td>
<td>0.049</td>
<td>Liking</td>
<td>-0.088</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Yellow</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Yellow and red</td>
<td>-0.021</td>
</tr>
<tr>
<td>F2 Color*Bell pepper liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=0:No orange</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=1:Orange</td>
<td></td>
</tr>
<tr>
<td>F3 Cut*Bell pepper liking</td>
<td>0.004</td>
<td>Liking</td>
<td>0.097</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=0:Slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=1:Cubes</td>
<td>0</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Bell pepper liking = 4.9

### b) Fruit mixes adults

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color*Grape liking</td>
<td>0.035</td>
<td>Liking</td>
<td>0.043</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td>0.164</td>
</tr>
<tr>
<td>F2 Product types*Grape liking</td>
<td>&lt;0.005</td>
<td>Liking</td>
<td>-0.199</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=0: No blueberries</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=1:Blueberries</td>
<td>0</td>
</tr>
<tr>
<td>F3 Cut*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=0:Slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=1:Cubes</td>
<td></td>
</tr>
<tr>
<td>F1 Color *Apple liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td></td>
</tr>
</tbody>
</table>

### c) Vegetable mixes (bell pepper) adolescents

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color*Bell pepper liking</td>
<td>0.044</td>
<td>Liking</td>
<td>-0.088</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Yellow</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Yellow and red</td>
<td>-0.021</td>
</tr>
<tr>
<td>F2 Color*Bell pepper liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=0:No orange</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=1:Orange</td>
<td></td>
</tr>
<tr>
<td>F3 Cut*Bell pepper liking</td>
<td>&lt;0.005</td>
<td>Liking</td>
<td>0.102</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=0:Slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=1:Cubes</td>
<td>0</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Bell pepper liking = 4.9

### Vegetable mixes adults

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td></td>
</tr>
<tr>
<td>F2 Product types*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=0: No blueberries</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=1:Blueberries</td>
<td>0</td>
</tr>
<tr>
<td>F3 Cut*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=0:Slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=1:Cubes</td>
<td></td>
</tr>
<tr>
<td>F1 Color *Apple liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0:Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td></td>
</tr>
</tbody>
</table>

### Fruit mixes adolescents

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0: Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td></td>
</tr>
<tr>
<td>F2 Product types*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=0: No blueberries</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F2=1:Blueberries</td>
<td>0</td>
</tr>
<tr>
<td>F3 Cut*Grape liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=0:Slices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F3=1:Cubes</td>
<td>0</td>
</tr>
<tr>
<td>F1 Color *Apple liking</td>
<td></td>
<td>Liking</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=0: Green</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>F1=1:Green and blue</td>
<td></td>
</tr>
<tr>
<td>Factors</td>
<td>p-value</td>
<td>Parameters</td>
<td>Parameter estimates</td>
</tr>
<tr>
<td>---------</td>
<td>---------</td>
<td>------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>F1 Color*Grape liking</strong></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td><strong>F2 Product types*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td><strong>F3 Product combinations*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td>*<em>F3 Product combinations <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Blueberry liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Blueberry liking</em></em></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Blueberry liking =4.6, Grape liking= 6.2, Apple liking = 6.1.

c) Fruit & vegetable mixes adults

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F1 Color*Grape liking</strong></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td><strong>F2 Product types*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td><strong>F3 Product combinations*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td>*<em>F3 Product combinations <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Blueberry liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Blueberry liking</em></em></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Blueberry liking =4.6, Grape liking= 6.2, Apple liking = 6.1.

<table>
<thead>
<tr>
<th>Factors</th>
<th>p-value</th>
<th>Parameters</th>
<th>Parameter estimates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F1 Color*Grape liking</strong></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td><strong>F2 Product types*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td><strong>F3 Product combinations*Grape liking</strong></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Bell pepper liking</em></em></td>
<td>-</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Bell pepper liking</em></em></td>
<td>p=0.026</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
<tr>
<td>*<em>F3 Product combinations <em>Bell pepper liking</em></em></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
</tr>
<tr>
<td>*<em>F1 Color <em>Blueberry liking</em></em></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
</tr>
<tr>
<td>*<em>F2 Product types <em>Blueberry liking</em></em></td>
<td>p&lt;0.005</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Blueberry liking =4.6, Grape liking= 6.2, Apple liking = 6.1.
<table>
<thead>
<tr>
<th>F3 Product combinations *Blueberry liking</th>
<th>Liking</th>
<th>F3=0: Green grapes</th>
<th>F3=1: Carrots</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1 Color *Carrot liking</td>
<td>Liking</td>
<td>F1=0: Yellow</td>
<td>F1=1: Yellow, red and orange</td>
</tr>
<tr>
<td>F2 Product types *Carrot liking</td>
<td>Liking</td>
<td>F2=0: No blueberries</td>
<td>F2=1: Blueberries</td>
</tr>
<tr>
<td>F3 Product combinations *Carrot liking</td>
<td>Liking</td>
<td>F3=0: Green grapes</td>
<td>F3=1: Carrots</td>
</tr>
</tbody>
</table>

Covariates appearing in the model are evaluated at the following values: Blueberry liking = 4.6, Grape liking = 6.2, Apple liking = 6.1

Authors: Mielby, Kildegaard, Gabrielsen, Edelenbos & Thybo (2011)
Supplementary Data
Click here to download Supplementary Data: Appendix21082011.docx
Preference, liking and wanting for beverages in children aged 9–14 years: Role of sourness perception, chemical composition and background variables

Heidi Kildegaard, Erik Tønning, Anette K. Thybo*

Department of Food Science, Faculty of Agricultural Sciences, Aarhus University, DK-5792 Aarslev, Denmark

**Abstract**

The purpose of the study was to examine the relationship between children's liking or wanting perception of sourness and food behavioural data in two types of beverages. In total 239 children (9–14 years old) evaluated apple juice and fruit drink in a design with 4 different dry matter concentrations. Multiple ranking was used to determine preference and perception of sourness, and a 5-point facial rating scale was used to assess liking and wanting. Children filled in questionnaires and BMI were registered. Multiple ranking showed that children on average had a high preference for versions of beverages perceived as less sour \((p = 0.05)\). A PCA on rating data (liking and wanting, respectively), segmented the children in 3–4 segments. A minor segment of children with high liking and wanting for the apple juice perceived as most sour was obvious. L-PLS regression revealed visually clear correlations between chemical measurements, liking, wanting and behavioural data.

1. Introduction

Childhood obesity is increasing worldwide (WHO, 1999). To minimise this development, it is important to understand what drives children's preferences as their food intake to a great extent is predicted by their preferences (Birch, 1979; Drewnowski, 1997, Drewnowski & Hann (1999); Baxter & Thompson, 2002; Cooke & Wardle, 2005; Liem & Zandstra, 2009; Perez-Rodrigo, Ribas, Serra-Majem, & Aranceta, 2003; Resnicow et al., 1997). Most children have a high preference for sweetness, which has been shown to be positively related to a high consumption of sugar-containing foods (Cooke & Wardle, 2005; Pangborn & Giovanni, 1984). Sweetness is associated with a high energy density, and consumption of high energy-dense foods can disrupt the energy balance causing obesity (Havermans & Jansen, 2007). As most beverages are sweet, high in energy density and heavily consumed by children, it will be advantageous to develop beverages that are less sweet and furthermore increase children's preferences for these beverages. Research has shown that perception of sweetness increases when sugar concentration increases (de Graaf & Zandstra, 1999; Zandstra & de Graaf, 1998) and Hewson, Hollowood, Chandra, and Hort (2008) illustrated that increased sugar in a model beverages system resulted in suppression of sourness perception. Baldwin, Goodner, and Plotto (2008) has shown a decrease in sour taste when sugar concentration in tomato puree is increased. Based on this, it was hypothesised that a decrease in sourness perception will occur when dry matter concentration is increased. To the authors knowledge no one has studied children's perception of sourness related to changes in dry matter content in beverages. Elucidating sourness perception is very important as sourness is a major reason for children rejecting food. To succeed in developing less sweet beverages for children, a study of children's perception of sourness is required.

Moreover, research has shown a decrease in children's preferences when acid concentration increases (Liem & Mennella, 2003). Liem and Mennella (2003) investigated the degree of sourness most preferred in children aged 5–9 years. They showed that generally preferences increased with decreasing levels of citric acid. However, more than one third of the children preferred extremely high degrees of sour taste. This third also experienced a greater variety of fruits, even lemons, when compared with other children (Liem & Mennella, 2003). Based on these findings, it was hypothesised that a relationship exists between children's food habits, liking and perception of sourness in beverages and fruits in general. If high preference for foods with high sourness is related to high consumption of fruits, it will, from a health aspect, be beneficial to change children's preferences making them accept more sour products.

The terms “preference” and “liking” are in many cases used interchangeably, and often preference is misused as a synonym...
for liking (Mela, 2001). It is important to make a distinction between the two terms, as the sense of the two terms is different. Preference indicates that among two or more products, one product is preferred over another, whereas liking refers to an immediate qualitative, hedonic evaluation of a product without a direct comparison to other products (Mela, 2001). In the present study both children's preferences and likings was examined. Research indicates that not only liking but also wanting plays an interdependent role in food choice and consumption in adults (Finlayson, King, & Blundell, 2007; Mela, 2006), which highlights the importance of a distinction between liking and wanting. Wanting is the intrinsic motivation to engage in eating a food, now or in the near future (Mela, 2006). Liking is a contributor to wanting, which presumably carries a component of anticipated pleasure, but liking is not enough to predict wanting (Mela, 2001). Studies focussing on children's liking and wanting as separate pathways for food choice are scarce. To the authors knowledge only one study has investigated both liking and wanting separately as pathways for children's food choice (Liem & Zandstra, 2009). Here it was concluded that the effect of liking on food choice is consistently larger than the effect of wanting.

Changing children's liking and wanting for beverages towards a more sour direction requires knowledge about the effect of sourness on liking and wanting. In this study children's liking and wanting for beverages with high energy density such as apple juice and fruit drink will be determined, as these are significant components of the daily intake of drinks. It is hypothesised that a relationship between children's liking and wanting for beverages varying in perceived sourness exists. Moreover it is hypothesised that there is a segment of children who likes and wants beverages with lower dry matter content than what is found in beverages available on the market today.

Therefore the objective was to examine:

1. Children's preference by multiple ranking.
2. Children's liking by rating.
3. Children's wanting by rating.
4. Children's perception of sourness by multiple ranking.

for two types of beverages, apple juice and fruit drink, varying in dry matter content, and to study the correlation between liking for the product and perception of sourness. Additionally, the children answered a questionnaire containing various background information and children's weight and height were registered. A multivariate correlation between the various data was aimed to improve the understanding of children's liking and wanting for beverages varying in sourness.

2. Materials and methods

2.1. Children

A local public school in DK-5792 Aarslev, Denmark, was contacted by letter and invited to participate in a study on children's liking for apple juice and fruit drink. Two hundred and thirty-nine children, 107 girls and 132 boys aged 9–14 years (mean age = 12.3 years) were recruited, and 195 of these completed the study, which required answers to all questions. For further descriptions, see Table 1.

Parents received a consent form which included a clear description of the study. Only children who returned a form signed by their parents participated in the study. The study was exempted from the need of formal ethical approval according to the rules of the Danish ethical committee, since it did not involve any physical interference with the children. The children's participation in the test was voluntary.

2.2. Products

Two types of beverages, apple juice and a common Danish fruit drink made of a mixture of juices from 11 different fruits and berries (plum, grape, orange, elderberry, cherry, pineapple, lemon, pear, black currant and prune), were used in the experiment. The apple juices and the fruit syrups for production of the fruit drink were received from a Danish juice producer, Rynkeby Foods A/S. Due to low storability of the non-pasteurised apple juice and fruit drink samples, the samples were mixed each day. Children's perception of sourness at altered dry matter content was of strategic interest due to the health aspects of foods. A design of four samples, varying in dry matter content, was made for both beverages by a recipe from Rynkeby Foods A/S (see Table 2). The acid content in both beverages was kept constant (apple juice = 8 g malic acid/l; fruit drink = 3.4 g citric acid/l) in order to ensure that the intensity of sourness was caused by the variation in dry matter content.

The sensory characteristics of sample 3 for both apple juice and fruit drink matched the most popular product on the commercial Danish market produced by Rynkeby Foods A/S. Table 2 shows the chemical compositions of the apple juices and fruit drinks.

The apple juices were yellow, the fruit drinks were red, and there were no visible colour differences between the four samples of each product.

2.3. Sensory evaluation

The study went on for four days with involvement of 50–60 children per day. Each day the children were divided into three groups consisting of 20–25 children per group. During the 4 days, a total of twelve groups were tested. Three girls refused to perform the test, 25 children did not go through the test procedure, 15 children did not fully complete the questionnaire and 2 children refused registration of body weight and height. This resulted in a complete dataset consisting of 195 children. Twelve children from the first test day were asked to repeat the test on the last test day to study repeatability of the experiment. The test sessions took place in the assembly hall of the school, which was a familiar place for the children. A trained instructor introduced the experiment in detail to the groups. Questions to the instructor were allowed if they did not understand the instructions they were offered. Except for clarifying questions, the children were told to remain silent during the test. The children were seated at large tables with a distance of 2 m to the next child. The first group started at 8.30 a.m., and each test session lasted for approximately 45 min with small
dexes (BMI; kg/m²) were calculated. Height and body weight were registered, and mean body mass in-

For these concepts have different meanings ("kunne lide" and

2.3.4. Rating of wanting

The children evaluated the samples again and determined their wanting for each of the four samples on the five point facial Likert Scale ranging from 1 = least wanted (sad face) to 5 most wanted (smiling face) (Russell & Worsley, 2007). The term ‘wanting’ was explained as a feeling of how much they fancy the juice or fruit drink right now.

2.4. Background information

2.4.1. Questionnaire

At the end of the test session, the children completed a questionnaire regarding information on gender and age, the amount of fruits consumed, which kind of fruits and vegetables they eat and their liking for sour fruits, beverages and candies. The questionnaire also contained information on the average consumption of four specific food items. This part of the questionnaire was con-

structed on the basis of a validated food frequency questionnaire (FFQ) adapted to fruit and vegetable intake used for children (Huybrechts, De Bacquer, Matthyss, De Backer, & De Henauw, 2006). The children were asked to indicate their answers on a list of frequen-

cies: every day; 4–6 days/week; 1–3 days/week; 1–3 days/month; never; I do not like it. The questionnaire is shown in the Appendix. To ensure independency between the various evaluations, the questionnaire was not handed out, until the results from the sen-

sory evaluation were given to the instructor.

2.4.2. Calculation of BMI

Height and body weight were determined without shoes to cal-

culate BMI (kg/m²). Height was measured on a Leicester height

measure, and weight was registered on an ADE (M30014) Elec-

tronic Floor Scale (Class III approved Scales). International gender

and age-adjusted reference percentiles (Cole, Bellizzi, Flegal, & Dietz, 2000) were used to classify children as underweight, normal weight or overweight.

2.5. Chemical analysis

Each day pH, content of dry matter, citric acid and malic acid were determined in two replicates of all samples of both apple juice and fruit drink to ensure that all samples had the proposed chemical composition each test day. The pH was measured by titration (PHM 92 LAB pH-meter Radiometer, Denmark). Acidity was determined as % malic acid by titration of the apple juice and as% citric acid in the fruit drinks (Metrohm titroprocessor Titri-

no 719 S, VWR & Bie & Berntsen, Denmark). The content of dry matter was expressed as grams of sugar/100 ml (Brix) and deter-

mined with a refractometer (RFM 840, VWR & Bie & Berntsen, Denmark).

2.6. Data analysis

Data analysis on chemical data was performed by using analysis of variance, ANOVA, to determine statistical variation between samples, day of production in pH and content of dry matter, citric acid or malic acid. A student’s t-test was performed to analyse if there were any differences between mean values of liking and wanting scores from the rating tests. Statistical analyses were per-

formed using SAS 9.1 software (SAS Institute, Inc., Cary, NC, USA).

Statistical significance was defined at p < 0.05. For the multiple ranking data on liking and perception of sourness, a nonparametric Friedman’s analysis of ranks was used to determine differences be-

tween samples (Newell & Macfarlane, 1987). If the $\chi^2$ statistic was significant (p < 0.05), a multiple comparison test, least square dis-

tance (LSD) rank test, was performed to determine significant dif-

ferences between samples.

The rating data on liking and wanting were analysed by multi-

variate Principal Component Analysis (PCA), LatentX, v. 1.00 (www.latentix.com, Latent5, Copenhagen, Denmark) to investigate the segments of children for liking and wanting of the samples. Full

Table 2

<table>
<thead>
<tr>
<th>Sample</th>
<th>Dry matter content g/100 ml (brix)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple juice 1(AP1)</td>
<td>11.1</td>
</tr>
<tr>
<td>Apple juice 2(AP2)</td>
<td>13.2</td>
</tr>
<tr>
<td>Apple juice 3(AP3)</td>
<td>15.5</td>
</tr>
<tr>
<td>Apple juice 4(AP4)</td>
<td>17.6</td>
</tr>
<tr>
<td>Fruit drink 1(F1)</td>
<td>9.1</td>
</tr>
<tr>
<td>Fruit drink 2(F2)</td>
<td>9.3</td>
</tr>
<tr>
<td>Fruit drink 3(F3)</td>
<td>9.9</td>
</tr>
<tr>
<td>Fruit drink 4(F4)</td>
<td>10.3</td>
</tr>
</tbody>
</table>
cross validation was used as validation criterion (Martens & Naes, 1989). A L-partial least square (L-PLS) regression was used to study the relationship between ratings of liking or wanting data (X-variables) and chemical data and data on various background variables (Y-variables) (Martens et al., 2005; Thybo, Kuhn, & Martens, 2004). Data from rating on liking and wanting from the repeatability group were also analysed by multivariate Principal Component Analysis (PCA) to determine children's repeatability of their ratings on liking and wanting. Full cross validation was used.

3. Results

3.1. Chemical measurements

The dry matter content of the four apple juices and fruit drinks are given in Table 2. In fruit drink, the dry matter content varies by 7–8 g/l between samples, and in apple juice, the difference in dry matter content is 22–24 g/l between the samples. The results from the ANOVA on pH, the content of dry matter, citric acid and malic acid showed no differences between the preparations on the four days neither in apple juice nor in fruit (data not shown).

3.2. Multiple ranking of preference and sourness

The results from Friedman’s analysis on preference and sourness perception illustrate that children were able to discriminate differences between the four samples of apple juice and fruit drink with respect to preference and perception of sourness. When analysing mean data for all children (Fig. 1a and b), and when separating them into gender (Tables 3 and 4) or age groups (data not shown), the children were able to differentiate preference and sourness intensity between the samples varying stepwise in degree of sourness. Only children in the 6th grades (mean age 12.3 years) could not perceive any difference between the fruit drinks. Fig. 1a and b illustrate the mean values for all children and statistical differences between the four samples of apple juice and fruit drink for preference and perceived sourness. For both figures, it is obvious that children’s preference increases when perception of sourness decreases. This progress is most well-defined for apple juices (Fig. 1a). Fig. 1a shows that children perceive a significant decrease in sourness between each stepwise change from apple juice 1 (11.1 g dry matter/l) to apple juice 4 (17.6 g dry matter/l). Furthermore, the figure shows that children prefer apple juice 3 (15.5 g dry matter/l) and 4 over apple juice 1 and 2 (13.2 g dry matter/l). There was no significant difference in preference between apple juices 3 and 4.

Fig. 1b shows mean values for the perception of sourness and preference for fruit drink for all children. The children perceive fruit drink 1 (9.1 g dry matter/l) as more sour than fruit drinks 2 (9.3 g dry matter/l) to 4 (10.3 g dry matter/l). There was no difference in sourness perception between fruit drinks 2 and 4, even though there was an increase of 0.4–0.6 g dry matter/100 ml between the three samples. The children preferred fruit drinks 3 (9.9 g dry matter/l) and 4 over fruit drinks 1 and 2. There was no difference in children’s preferences between fruit drinks 1–3 or between fruit drinks 3 and 4.

The effect of gender on preference and perception of sourness in apple juice was also analysed, and the results from this analysis are seen in Tables 3 and 4.

Table 3 shows that girls perceived apple juice 1 as more sour than apple juices 3–4 and apple juice 2 as more sour than apple juice 4. They did not perceive any differences in sourness between the apple juices 1 and 2, 2 and 3 or 3 and 4. Boys perceived apple juice 1 as more sour than apple juices 2–4, and apple juice 2 as more sour than apple juice 4. The girls preferred apple juices 2–4 over apple juice 1. There were no differences in preferences for apple juices 2–4. Boys preferred apple juices 2–4 over apple juice 1, and they preferred apple juices 3 and 4 over apple juice 2. The rank sums in Table 3 show that girls perceive fruit drink 1 as more sour than fruit drinks 3 and 4. There were no differences between the other fruit drinks. Boys could not perceive any differences between the fruit drinks. Girls preferred fruit drink 4 over fruit drinks 1 and 2 and fruit drink 3 over fruit drink 1, and boys had an equal preference for the four fruit drinks.

3.3. Segmentation of children’s liking and wanting for apple juice and fruit drink

Children's liking and wanting scores for the four apple juices were studied by PCA to obtain detailed information about the individual children’s scores (Fig. 2a and b). A PCA on liking scores for apple juice (Fig. 2a) showed that 53% of the variation in the data

![Table 3](image)

**Table 3**

Differences between genders in rank sums for perception of sourness and preference of apple juice.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Rank sum girls sourness</th>
<th>Rank sum boys sourness</th>
<th>Rank sum girls preference</th>
<th>Rank sum boys preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple juice 1 (AP1)</td>
<td>304&lt;sub&gt;a&lt;/sub&gt;</td>
<td>381&lt;sub&gt;a&lt;/sub&gt;</td>
<td>158&lt;sub&gt;b&lt;/sub&gt;</td>
<td>185&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
<tr>
<td>Apple juice 2 (AP2)</td>
<td>252&lt;sub&gt;a&lt;/sub&gt;</td>
<td>301&lt;sub&gt;b&lt;/sub&gt;</td>
<td>238&lt;sub&gt;c&lt;/sub&gt;</td>
<td>271&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Apple juice 3 (AP3)</td>
<td>198&lt;sub&gt;a&lt;/sub&gt;</td>
<td>254&lt;sub&gt;bc&lt;/sub&gt;</td>
<td>250&lt;sub&gt;b&lt;/sub&gt;</td>
<td>336&lt;sub&gt;b&lt;/sub&gt;</td>
</tr>
<tr>
<td>Apple juice 4 (AP4)</td>
<td>159&lt;sub&gt;b&lt;/sub&gt;</td>
<td>205&lt;sub&gt;c&lt;/sub&gt;</td>
<td>267&lt;sub&gt;b&lt;/sub&gt;</td>
<td>352&lt;sub&gt;c&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

Different lettering indicates statistically significant differences on p < 0.05. See Table 2 for further details about the samples.
was explained by one significant principal component (PC1), while 27% of the variation was explained by PC2. A large proportion of the liking scores are situated to the right along PC1 illustrating that a large group of children liked apple juices 3 and 4, which were the least sour apple juices. However, approximately ¼ of the liking scores is situated to the left along PC1 indicating a segment of children liking the two most sour juices, apple juices 1 and 2. The PCA plot of the wanting scores for apple juice (Fig. 2b) showed similarly that 54% of the variation was explained by PC1, while 24% of the variation was explained by PC2. Again a large proportion of children is situated to the right along PC1 illustrating a large segment of children who wants apple juices 3 and 4. A small segment of children is situated to the left along PC1 indicating a segment who wants the two most sour juices, apple juices 1 and 2.

PCA was also applied on liking and wanting scores for fruit drink, and as expected, due to the small range in dry matter content, segmentation of children was not as evident as for the apple juices, and the results are not shown.

3.4. Liking and wanting

When analysing rating data for both apple juice and fruit drink as means over all children, Fig. 3a and b shows that there is a very similar progression in liking and wanting with increased dry matter content. However, the mean scores for wanting are lower than liking scores in both beverages. Fig. 3a shows that when the gap between mean rating for liking and for wanting is larger, the apple juice is perceived to be less sour. This variation is not seen in Fig. 3b. A t-test on mean values for liking and wanting on each of the four samples of both apple juice and fruit drink revealed that the mean values are significantly different from each other. In the case of apple juice, the mean values for liking and wanting scores become even more different, the less sour the apple juice is perceived (AP1 \( p = 0.0019 \) – AP4 \( p < 0.0001 \)). The difference in liking and wanting scores for fruit drink is equal between the samples \( p < 0.0001 \).

A multivariate (PLSR) correlation between liking and wanting data for all children gave a correlation coefficient of \( r = 0.6 \) (data not shown).

3.5. L-PLS

In Fig. 4a the results from the L-PLS regression on liking data of apple juice, chemical measurements and background variables are shown. PC1 and PC2 span the variation in liking for the four apple juices. Along PC1 (explaining 54% of the variation) to the right, a high concentration of liking scores is located illustrating that the least sour apples juices are highly liked by a large number of children. In order to explain the liking of the four apple juices, a causal segmentation is indicated in Fig. 4a. The segment with high liking for one of the least sour apples juice (AP3) is inversely correlated with a small segment of children preferring the most sour apple juice (AP1). In the segment liking apple juice 3 (AP3), a high correlation between liking for AP3 and overweight children and a high intake frequency of sweet fruits and vegetables in general are observed. The liking scores in this area are also correlated to high dry matter content in apple juice. Additionally, there is a correlation between high liking for sour apple juice (AP1), normal weight, reporting a high intake of juice (each day), high liking of sour fruit and low intake of many fruits and vegetables. Children were also classified as underweight, but very few fell into that category and therefore it is not shown in the plot.

Twenty-seven percent of the variation is explained by PC2, and this component spans the variation in gender and age. In the upper

Fig. 2. Children’s (193) liking (a) and wanting (b) for four apple juices analysed by Principal Component Analysis (PCA); x: boys; o: girls. See Table 2 for further details about samples.

Fig. 3. Mean ratings of liking (■) and wanting (●) for apple juices 1–4 (a) and fruit drinks 1–4 (b) for 195 children. See further details about the samples in Tables 2 and 3.
left corner of the L-PLSR plot, another very small segment of children preferring apple juice 2 (AP2) is found. These children resemble to a higher extent the segment liking a sour apple juice (AP2) by reporting that they like sour candy, sour juice, and that they drink juice very often and never eat fruits. The segment is dominated by girls and children aged 9–12 years. In the lowest right corner of the PCA plot, a larger segment of children liking the least sour apple juice 4 (AP4) is present. This segment is primarily composed of boys and children aged 13–15 years. The scores of this segment are dominated by the parameters that are inversely correlated to the ones described above, e.g., the children report that they never drink juice, and that they eat vegetables and fruit very often.

In Fig. 4b results from the L-PLSR regression on data on wanting, chemical measurements and background variables are shown. PC1 spans the variation (explaining 53% of the variation) in liking for the most sour and the least sour apple juice, acid, dry matter content, weight, gender and sour fruit, candy and juice. Approximately 30% of the variation is explained by PC2, and this component spans the variation in age. The children who want apple juices 1 and 2 reported that they like sour juice, sour candy and sour fruit and they are mainly characterised as being normal weight and girls.

The scores are correlated with a high content of malic acid as well. A greater part of the children want the less sour apple juices 3 and 4. These children are characterised as boys and overweight.

4. Discussion

The results from the present study show an inverse relationship between preference and perception of sourness in children in both apple juice and fruit drink. These results are in agreement with other findings on both young adults and children (Chauhan & Hawrysh, 1988; Liem & Mennella, 2003; Liem, Westerbeek, Wolterink, Kok, & de Graaf, 2004; Moskowitz, Kumaraiah, Sharma, Jacobs, & Sharma, 1975, 1976). Liem and Mennella (2003) and Liem et al. (2004) studied children aged 5–9 years, and here the results showed that increased sourness intensity resulted in a decrease in preference in most children. However, they also found a segment of children who preferred the extremely sour tastes, and their preference increased with increasing levels of citric acid. These children reported that they preferred a variety of other sour-flavoured food items, which suggests that they indeed preferred the sour taste (Liem & Mennella, 2003; Liem et al., 2004).

In the present study no significant differences in children's preference between apple juice 3 and 4 was found indicating that dry matter content do not need to be higher than 15.5 g/l to ensure children's preferences. The optimum in preference for apple juices 3 and 4 indicates that the dry matter/acid ratio can be altered and optimised in relation to children's preference for beverages. The result was further confirmed when children were separated into genders. However, it is important to notice that girls perceived apple juice 2 (13.2 g dry matter/l) as more sour than apple juice 4 (17.6 g dry matter/l), but there was no difference in preference for the two apple juices. This means that girls accept lower dry matter content than boys, and therefore they prefer a more sour apple juice than boys.

In both apple juice and fruit drink a decrease in sourness perception following an increase in dry matter content was registered. However, this result was most pronounced in apple juice probably caused by a larger range in dry matter content in apple juices than in fruit drink. Looking at the fruit drink it is apparent that the chemical differences between the samples are relatively small. The dry matter content only ranged from 9.1 to 10.3 g dry matter/l which affects the perception of sourness. Nevertheless, most of the children were able to register the small differences between the fruit drink samples on a significant level. The small range in dry matter content between the fruit drink samples explains why the difference between the preference and perception of sourness in apple juice is larger than in fruit drink, as the range in dry matter content in apple juice varied from 11.1 to 17.6 g dry matter/l.

Moreover the different types of acids in the beverages and the difference in acid concentration between the two beverages (8 g malic acid/l in apple juice and 3.4 g citric acid/l in fruit drink) could be a possible explanation for the difference in decrease in sourness perception between the two products (Savant & McDaniel, 2004). The decrease in perception of sourness related to increase in sugar has also been studied by other researchers. Hewson et al. (2008) showed that in a citrus flavoured model beverage system the addition of sugars resulted in a suppression of sourness perception (Hewson et al., 2008) and Baldwin et al. (2008) have shown that addition of sugar decreases sour taste in tomato puree (Baldwin et al., 2008).

When looking at the PCA plots (Fig. 2a and b) a similarity in the segments between children's liking and wanting for apple juice is observed, as the scores in the two PCA plots are situated almost identically despite a shift in position of apple juices 3 and 4. Moreover a relatively high positive correlation was found between
liking and wanting supporting this similarity (data not shown). However, the correlation coefficient also shows that rating of wanting cannot be fully predicted by children’s liking. Nevertheless, liking is obviously one of the major contributors to wanting, which presumably carries a component of anticipated pleasure and hedonic experience (Mela 2006). Fig. 3a and b also supports which presumably carries a component of anticipated pleasure and hedonic experience (Mela 2006). Fig. 3a and b also supports this similarity (data not shown).

In the present study, liking was determined by multiple ranking and rating. An agreement between multiple ranking (Fig. 1a and b) and a 5-point facial intensity scoring of liking (Fig. 3a) was observed, which validated children’s scores and the appropriateness of the two sensory methods. More researchers found that the smiley scale is an appropriate and reliable instrument for testing the attitude of children (Davies & Brember, 1994; Kroll, 1990; Moskowitz, 1985). Kimmel, Sigmangrant, and Guinard (1994) suggests a 7-point scale with smiley faces and words to express liking for children. In this study a 5-point smiley scale was used to secure that the scale was cognitively understandable for the children.

Combining data from the chemical measurements, background variables and liking data or data on wanting using multivariate regression by L-PLS gives a correlation between these data which can be used to elucidate the influence of habits on children’s liking and wanting (Martens et al., 2005; Thybo et al., 2004). From the L-PLS analysis, a segment composed of approximately one fourth of the children preferring the two juices that were perceived as most sour seems to exist, which was also found by Liem and Mennella (2003). Likewise they found that these children had a high liking for extremely sour foods, and this that liking for sour taste is generalised to other foods (Liem & Mennella, 2003). Furthermore, the analysis presents a segment of normal weight children who never eat fruits and vegetables, and to the opposite a segment of overweight children who like a lot of different fruits and vegetables. This conflict with the idea of making children eat more fruit and vegetables to avoid overweight. Maybe these children are just very keen of foods and have a wide repertoire of likings, which make them eat a lot.

The L-PLS multivariate correlation between the various data proved to be a visual method to achieve an overview of parameters correlated to children’s liking and wanting, which may increase the understanding of liking and wanting as illustrated by (Martens et al., 2005; Thybo et al., 2004).

In the present study children’s perception of sourness, preferences, liking and wanting for two beverages that differs in dry matter content were examined. It would have been appropriate to examine the perception of sweetness of the beverages too and the authors recommend that more studies are performed to elucidate children’s perception of both sourness and sweetness in relation to changes in dry matter content. Since one of the underlying aims in this study was to develop more healthy beverages to children sourness perception was emphasised as one of the main reasons for children rejecting foods is the degree of sourness.

5. Conclusion

This study shows an inverse correlation between preference and perception of sourness in children, as preference decreased when the perception of sourness increased in both apple juices and fruit drinks. However, the results indicate that dry matter content should not exceed 15.9 g/l as children’s preferences are stabilized at this point. This knowledge can be used in future innovation of food products and will form the basis for investigating the influence of food composition and complexity on liking of stepwise altered products.

The finding of a segment of children who like the apple juice that was perceived as most sour and the relation to food habits is of high relevance for healthier product development. A significant agreement between multiple ranking and a 5-point facial intensity score was established, which validated children’s scores and the appropriateness of using the two sensory methods.

Acknowledgements

The Danish Agency for Science, Technology and Innovation is greatly acknowledged for financial support to the project (FoSu-project: step by step changing of children’s preferences for healthier foods, J. No. 3304-FSE-06-0504). Thanks are due to Rynkeby Foods A/S, Arla Foods amba and Dairy Foods A/S for delivering the products and to Mette Pedersen, Lone Storm and Lone Borum for technical assistance.

Appendix A

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Gender: Girl [ ] Boy [ ]</td>
</tr>
<tr>
<td>Age:</td>
<td>Grade:</td>
</tr>
</tbody>
</table>

Food groups

<table>
<thead>
<tr>
<th>How much do you consume a day?</th>
<th>How often do you consume the following products?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits</td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>□ None</td>
</tr>
<tr>
<td>Pear</td>
<td>□ 1 Piece</td>
</tr>
<tr>
<td>Banana</td>
<td>□ 2 Pieces</td>
</tr>
<tr>
<td>Grape fruit</td>
<td>□ 3 Pieces</td>
</tr>
<tr>
<td>Orange</td>
<td>□ 4 Pieces</td>
</tr>
<tr>
<td>Plum</td>
<td>□ 5 Pieces</td>
</tr>
<tr>
<td>Peach</td>
<td>□ 6 Pieces</td>
</tr>
<tr>
<td>Pineapple</td>
<td>□ More than 6 pieces</td>
</tr>
<tr>
<td>Melon</td>
<td></td>
</tr>
<tr>
<td>Kiwi</td>
<td></td>
</tr>
<tr>
<td>Other fruits</td>
<td></td>
</tr>
</tbody>
</table>

Which fruits do you consume? (More than one marking is allowed)

Juice

| □ Never |
| □ 1–3 days per month |
| □ 1–3 days per week |
| □ 4–6 days per week |
| □ Every day |

Vegetables

| □ Never |
| □ 1–3 days per |

Thank you for your participation in this study.
Appendix A (continued)

<table>
<thead>
<tr>
<th>Food groups</th>
<th>How much do you consume a day?</th>
<th>How often do you consume the following products?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>month</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ 1–3 days per week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ 4–6 days per week</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ Every day</td>
</tr>
</tbody>
</table>

Which vegetables do you consume? (More than one marking is allowed)
- Tomato
- Cucumber
- Carrot
- Salad
- Maize
- Peas
- Broccoli
- Beans
- Leek
- Other vegetables

Yoghurt
- □ Never
- □ 1–3 days per month
- □ 1–3 days per week
- □ 4–6 days per week
- □ Every day

Do you like:
- Sour fruits
  - □ Yes □ No
- Sour juices/fruit drinks
  - □ Yes □ No
- Sour candy
  - □ Yes □ No

References


Erratum to “Preference, liking and wanting for beverages in children aged 9–14 years: Role of sourness perception, chemical composition and background variables” [Food Quality and Preference 22 (7) (2011) 620–627]

Heidi Kildegaard, Erik Tønning, Anette K. Thybo

Department of Food Science, Faculty of Agricultural Sciences, Aarhus University, DK-5792 Aarslev, Denmark

The authors would like to draw your attention to the fact that there is an error in Fig. 3, on page 624 of their paper. The correct figure is reproduced below.

Fig. 3. Mean ratings of liking (○) and wanting (■) for apple juices 1–4 (a) and fruit drinks 1–4 (b) for 195 children. See further details about the samples in Tables 2 and 3.

The publisher would like to apologise for any inconvenience this may have caused to the authors of this article and readers of the journal.

DOI of original article: 10.1016/j.foodqual.2011.03.005

* Corresponding author. Tel.: +45 8999 3405; fax: +45 8999 3495.
E-mail address: Anette.Thybo@agrsci.dk (A.K. Thybo).

0950-3293/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.foodqual.2011.07.003
EFFECT OF INCREASED FRUIT AND FAT CONTENT IN AN ACIDIFIED MILK PRODUCT ON PREFERENCE, LIKING AND WANTING IN CHILDREN

H. KILDEGAARD, M.M. LØKKE and A.K. THYBO

Department of Food Science, Faculty of Science and Technology, Aarhus University, Kirstinebjergvej 10, DK-5792 Aarslev, Denmark

ABSTRACT

New strategies for changing children’s liking in a more healthy direction are needed. Modulating food products by masking techniques have shown to convert dislikes into likes. In this study, children’s (n = 204, 9–14 years) perception of sourness, preferences, liking and wanting for acidified milk products (AMP) with variation in fat (0.5% versus 3.5%) and fruit content (5–20%) were investigated. Multiple ranking and PARAllel FACtor analysis were used to evaluate ranking and rating data, respectively. The results show that high-fat AMP is preferred at low fruit content, whereas fat content has no influence on liking at high fruit contents. Children like and want AMPs with 15–20% fruit more than AMPs with 5–10% fruit. Segments of children rank and rate the AMPs significantly different. Finally, a high correlation between liking and wanting is observed. These results give the food industry an option to produce new healthy food products to children without loss in children’s liking.

PRACTICAL APPLICATIONS

From a health perspective, the effects of increasing fruit content in acidified milk product on children’s hedonic perceptions are very important. There is a serious need for shaping children’s dietary habits in a more healthy direction to decrease the negative development in childhood obesity. These results provide knowledge about some of the main factors driving children’s food choice in both the eating and the purchase situations. Knowledge about children’s drivers toward healthy foods provides important information in product development of high fruit products. Moreover, the results are useful for researchers, producers, manufacturers and health professionals as a first step to design public health policies and consumer education strategies. The various methodologies presented in the paper can also be implemented in the study of children’s liking and wanting for other foods.

INTRODUCTION

An adequate fruit and vegetable intake provides essential nutrients and nutritive compounds, and is considered an important part of a healthy lifestyle. However, it is widely reported that most children eat less than the recommended amounts of fruits and vegetables (Guenther et al. 2006). A population survey estimated that less than 10% of U.S. children aged 4–8 years consume the recommended daily amount of fruit and vegetables (Guenther et al. 2006). The Danish health authorities recommend that children above the age of 10 years consume 600 g of fruit and vegetables every day (Hallund et al. 2007), but only 16% of the children meet these recommendations (Fagt et al. 2008). Thus, it is critical to develop strategies to increase fruit and vegetable intake in children.

Children are more involved than ever in choosing which food products to purchase and which products to eat (Chambers 2005; Popper and Kroll 2005), and their food choices are highly related to their preferences (Liem et al.
In a choice-based study on children, Sondergaard and Edelenbos (2007) showed a high agreement between children’s favorite vegetable and their actual choice. Gibson et al. (1998) found that children’s (9–11 years old) preferences for healthy food products were a more significant predictor of their intake than either parental intake or parental attitudes to child feeding. This underlines the importance of children’s preferences in food choice.

Both taste and mouth feeling are significant contributors to liking and to the evaluation of foods, but other sensory characteristics of food contribute to the responses as well. Foods are valued in accordance with the impression perceived by the sum of all the senses (taste, odor, audio, vision and mouth feeling). Texture is an essential sensory attribute that plays an important role in the evaluation and appreciation of many foods, and one of the major components that have an effect on texture is fat (Tuorila et al. 1995). Fat also affects flavor, indicating that fat has a high influence on the oral sensation of foods (Janhøj et al. 2006). Dairy fat in milk and cream contributes to product smoothness, creaminess, thickness and viscosity. In general, the appreciated sensory properties of milk are highly influenced by its fat content (Frost et al. 2001).

The oral perception of fat has traditionally been considered to rely mainly on texture and olfaction, but recent findings identified a protein receptor (CD36) responsible for sensing fat in the taste buds in rats (Khan and Besnard 2009). Whether CD36 or other putative lipid receptors are expressed in taste receptor cells of humans is currently unknown. However, studies have shown that healthy adult subjects can detect both saturated and unsaturated long-chain fatty acids when olfactory and somatosensory cues are minimized (Chale-Rush et al. 2007). This indicates that chemoreception of dietary lipids in humans is plausible.

The oral appreciation of fat can be used to increase liking of a disliked food by using flavor nutrient learning. The result of flavor nutrient learning is that one learns to associate the flavor with the positive post-ingestive effects induced by the nutrient content, which will probably lead to an increased liking of the flavor. This caloric conditioning of flavor liking has repeatedly been investigated in children. Zeinstra et al. (2009) used different vegetable flavors to increase children’s vegetable preferences, but flavor nutrient learning did not occur, although others have shown that children developed a preference for drinks containing high-energy (carbohydrate) relative to low-energy drinks (Birch et al. 1990) and for high-fat paired flavors over low-fat flavors (Johnson et al. 1991; Kern et al. 1993). These results indicate that flavor nutrient learning can be used to change preferences.

Flavor release is another important parameter affected by fat content. A higher content of fat results in a slower release of flavors (Hatchwell 1996). Time intensity studies of flavor in ice cream have shown that an increase in fat content prolonged the time to reach maximum intensity in vanilla flavor and prolonged flavor release of strawberry and fruitiness (Lallemand et al. 1999). Frost et al. (2001) also found that an elevated fat content in milk affects the sweet taste.

During sensory evaluation assessments, various masking techniques have been carried out to investigate how different food characteristics influence the sensory perception of the food. Visual masking techniques are frequently employed to distinguish color differences between samples and minimize perceptual bias, i.e., beverages. Ross et al. (2008) studied the influence of visual masking techniques on the aroma and flavor assessment in red wine in both trained and consumer sensory panels. These results indicated that visual masking techniques may influence both trained and consumer panel evaluation of aroma and flavor attributes of red wine. In a study investigating the masking effect of fat, Madsen and Ardo (2001) have shown that it is possible to mask sensory attributes by changing fat and texture in the food product. They showed that for cheese, an increase in fat content (45%) has a masking effect on bitterness in contrast to low-fat cheese (20%).

Perception of sensory attributes is related to acceptance and preference of foods. Acceptance refers to degrees of liking and disliking, whereas preference indicates that among two or more products, one product is preferred over another (Mela 2001; Hein et al. 2008). To succeed in developing new healthier foods with changes in composition and sensory quality, it is of utmost importance that acceptance, preference, liking and wanting are optimized. Mela (2001) suggests liking to be a contributor to wanting. Previous studies measured liking and wanting as one concept (Fisher and Birch 1999a, b) or measured one of the two pathways (Jansen et al. 2008). Studies that focused on children’s liking and wanting as separate pathways for children’s food choice are limited. Among the few are Liem and Zandstra (2009), who concluded that the effect of liking on food choice is consistently larger than the effect of wanting. Kildegaard et al. (2011) also found a high correlation between liking and wanting.

Based on the above reviewed literature, it is hypothesized that children’s preferences, liking and wanting for acidified milk products (AMP) are dependent on fat and fruit content, and that there is a significant positive correlation between liking and wanting. Moreover, an inverse correlation between preference and sourness perception is hypothesized. Therefore, the aim of the study was to examine children’s perception of sourness, preference, liking and wanting of AMP with four levels of fruit (strawberry) content considered at two levels of fat content.

Based on the hypotheses, children’s preference and sourness perception were examined by multiple ranking, and their liking and wanting by the use of rating scales. This was done to improve the understanding of children’s liking and wanting for AMPs varying in fat and fruit content.
MATERIALS AND METHODS

Participants

A Danish public school was contacted by letter and invited to participate in a study on children’s liking for various AMPs and beverages. In total, 238 children, 107 girls and 132 boys, aged 9–14 years (mean age = 12.3 years) agreed to participate in the study, and 204 children completed the study determined by a full answer of all questions. Further information is provided in Table 1.

The study was exempted from the need of formal ethical approval according to the rules of the Danish ethical committee because it did not involve any physical interference with the children. Informed consent was obtained from the children’s parents prior to participation. Children’s participation in the test was voluntary.

Products

The product categories comprised of two AMPs with low- and high-fat content added with strawberry marmalades with four levels of strawberry content. The AMPs differed in fat content: (1) AMP low fat (LF) contained 0.5% fat; and (2) AMP high fat (HF) contained 3.5% fat. Both AMPs were composed of milk and milk proteins (80% casein and 20% whey), and LF contained 3 g protein/100 g AMP, and HF contained 3.3 g protein/100 g AMP. The AMPs were homogenized, pasteurized and acidified with milk acid cultures and cultures of Lactobacillus acidophilus. The AMPs were received from a Danish dairy, Arla Foods amba (Viby, Denmark). The strawberry marmalades were received from a Danish supplier of flavors, Dairy Fruits A/S (Odense, Denmark). The content of strawberry varied from 20 to 80% in the marmalade, but in the final samples, the strawberry content varied from 5 to 20% as the dosage of marmalade to the AMPs was 25% in all samples (see Table 2). Saccharose concentration was held constant between the samples. Owing to low storability of the nonpasteurised marmalades, the samples were mixed each day. Table 2 shows the composition of the different AMPs.

A typical Danish fruit AMP contains, on average, 8% fruit depending on the brand and type of fruit. All samples had a light red color with visible differences in the shade of color because of the differences in the amount of added marmalade.

Study Design

The study proceeded over a period of 4 days with daily tests of 50–60 children. Each day, the children were divided into three groups with 20–25 children in each group. Three girls refused to perform the test, 13 children did not complete the test procedure and 18 children did not fully complete the additional questionnaire. This resulted in a complete data set consisting of 204 children. Thirteen children from the first test day were asked to repeat the test on the last test day to ensure repeatability of the experiment. The test sessions took place in the assembly hall at the school, which was a well-known place for the children. A trained instructor introduced the experiment in detail to the groups. The children were allowed to ask questions to the instructor if they did not understand the instructions they were given. Except for asking clarifying questions, the children were told to remain silent during the test to avoid peer influence, thereby assuring unbiased opinions (Popper et al., 2005).
and Kroll 2005). The children were seated at large tables with 2-m space between each other. The first group started at 8.30 a.m., and each test session lasted for approximately 45 min, including small breaks where the children remained seated. The children received four servings (products): (1) four samples of AMP_LF varying in fruit content; (2) four samples of AMP_HF varying in fruit content; (3) four samples with yellow apple juice; and 4) four samples with red fruit drink. The serving order of the four product categories were randomized between the 12 groups of children. The AMP samples were served in transparent plastic containers in portions of 100 mL, and each sample container was coded with a random three-digit number. A teaspoon was handed out to each child. The samples were served at room temperature, and the amount of which each child consumed of the samples was voluntary. The serving order of the four samples for each of the two AMPs was randomized between the children. The results from the apple juice and fruit drink are published elsewhere (Kildegaard et al. 2011).

Sensory Measures

Preferences and Perception of Sourness. Children’s preferences and sourness perception of the two AMPs were measured by a multiple ranking test. When assessing preferences, the children were presented with the four variations of each product category. The children were asked to taste each of the four samples in turn and note which one they preferred the most. Hereafter, they were asked to taste the remaining three samples again and indicate which of the three they preferred the most. This procedure continued until a ranking order of preference was established. The least liked sample was assigned 1 point; the most liked was assigned 4 points. All other samples were given points between 1 and 4 according to their position in the preference rank-order. The reliability and validity of such measures of preference in children have previously been demonstrated (Birch and Sullivan 1991; Guthrie et al. 2000). Subsequently, the children should rank the products in relation to perception of sourness. Prior to this, they mixed the ranking order of preference by moving around the samples, and they tasted the four samples again and ranked these with respect to sourness intensity ranging from the most sour to the least sour. The least sour sample was assigned 1 point, whereas the most sour was assigned 4 points. All other samples were given points between 1 and 4 according to their position in the preference ranking order. The reliability of measuring sourness perception in children aged 5–9 years old by multiple ranking has previously been demonstrated (Liem and Mennella 2003). In both ranking tests, the children were allowed to rinse their mouth with water after tasting each of the samples.

Liking. The children were asked to indicate their degree of liking of the samples on a simple 5-point facial scale ranging from 1 point = extremely disliked (sad face) to 5 points = extremely liked (smiling face). The instructor showed the children pictures of five different drawings of faces representing (1) extremely liked; (2) disliked; (3) maybe liked; maybe disliked; (4) liked; and (5) extremely liked, and carefully explained the meaning of the five faces ensuring that everyone understood the scale. The explanation was given by saying:

This is the face you make when you do not like something at all. This is the face you make when you do not like something. This is the face you make when you neither like nor dislike it. This is the face you make when you just like something. This is the face you make when you like something very much.

Then, the children tasted the samples again, and they were asked to score the samples on the 5-point facial scale. This procedure continued until all the samples were scored for liking. The applied procedure has previously been used and validated on children (Birch and Sullivan 1991; Leon et al. 1999; Guthrie et al. 2000).

Wanting. To obtain information about children’s wanting for the samples, they were asked to taste the samples again and rate them on the 5-point facial scale ranging from 1 point = I really do not want to eat this (sad face) to 5 point = I really do want to eat it (smiling face) (Russell and Worsley 2007). The instructor explained the meaning of the five faces by saying:

This is the face that you make when you really do not want to eat it – 1 point. This is the face that you make when you do not want to eat it – 2 point. This is the face that you make when you do not know – 3 point. This is the face that you make when you want to eat it – 4 point. This is the face that you make when you really want to eat it – 5 point.

Previous studies have used similar explicit measurements of wanting (Jansen et al. 2008).

Data Analysis

For the multiple ranking data on preference and perception of sourness, a nonparametric Friedman’s analyses of ranks were used to determine differences between samples (Newell and MacFarlane 1987). If the $\chi^2$ statistic was significant ($P < 0.05$), a multiple comparison test, Latin square distance (LSD) rank test, was performed to determine significant differences between samples. A Student’s t-test was performed to analyze if there were any differences between mean values of liking and wanting scores from the rating tests. Statistical analyses were performed using SAS 9.1 software (SAS Institute, Inc., Cary, NC). Statistical significance was defined at $P < 0.05$. 
The three-way nature of the rating data on liking and wanting (samples × children × rating) was analyzed by PAR-allel FACtor analysis (PARAFAC) (Bro 1997a; Cocchi et al. 2006a), a three-way multivariate explorative tool. The PARAFAC is a generalization of principal component analysis (PCA) to higher order arrays (Bro 1997b). The PARAFAC model was built with 2 components because of a reasonable compromise of acceptable residual sum of squares, core consistency and explained variance and because the added component led to models with interpretable structure. The PLS-toolbox 5.8 (Eigenvector research, Manson, WA, USA) was used for PARAFAC modeling and the rating data was pre-treated with mean centering. Based on the loading plot a visual segmentation of children was carried out and 4 groups were formed according to their position in the four quadrants. \( \chi^2 \) statistics was used to find significant \( (P < 0.05) \) variation in the rating data in each group according to observed and expected occurrence of age and gender. Furthermore Friedman’s analyses of ranks were repeated to clarify if the different groups ranked the samples equally. If the \( \chi^2 \) statistic was significant \( (P < 0.05) \) LSD rank test was performed to determine significant differences between samples.

RESULTS AND DISCUSSION

Children’s Preferences

The results from Friedman’s analysis of ranks for data on preference and sourness perception illustrate that children are able to discriminate differences between only a few of the four samples of the low and high fat AMPs. In the subsequent discussion, HF_5–20% refers AMP_HF5–20% whereas LF_5–20% refers AMP_LF5–20%. For HF, the children perceive HF20% as more sour than HF5% (Fig. 1a), which indicates that an increase in the amount of fruit added to the HF increases sourness in the AMP. This is seen even though the level of saccharose is constant (Table 2). In contrast, children are not able to distinguish the four samples of LF (Fig. 1b) in relation to sourness. An elevated fat content was also seen to affect taste in a study by Frost et al. (2001), which further supports the results.

Figure 1a,b also show that small differences are present in preference when increasing the fruit content in the AMPs. However, a significant increase in preference is only observed between LF20% over LF5%. In summary, the data analysis of ranking data on all children’s preferences and sourness perception show only small effects of increasing the amount of fruit on preference and sourness perception. No conclusion can therefore be drawn on the influence of increasing fruit in AMPs on children’s preferences and sourness perception using the ranking methods and means over all children.

The ranking data from all children were segmented into gender and age groups to study if more information about the effect of increased fruit content on preference and sourness can be extracted. The effect of gender on preference and perception of sourness in HF and LF is seen in Table 3. The results show that girls prefer LF20% over LF5% whereas no differences in preference for the four samples of HF are observed. From Table 3, it is also apparent that girls do not perceive any differences in the degree of sourness. The boys have an equal preference for all samples of both LF and HF, but they perceive HF20% as more sour than HF5%. So even though the boys find HF20% significant more sour than HF5%, they prefer the samples equally. In summary, a segmentation of the children with respect to age and gender does not provide additional insights into the effect of increased fruit content on preference and sourness perception.

FIG. 1. RANKING OF PREFERENCE AND SOURNESS PERCEPTION

Mean rankings of preference (▲) and perceived sourness (●) for HF (a) and of LF (b). See further details about samples in Table 2. Significant differences between samples within each attribute are given by different letters.
not lead to more obvious and cognitive clear differences in preference and sourness perception among the samples varying in fruit content.

**Children’s Preferences and Liking**

Often the terms “preference” and “liking” are used interchangeably, and preference is frequently misused as a synonym for liking (Mela 2001). It is important to separate the terms as the sense of the terms is different. Preference indicates that among two or more products, one product is preferred over another, whereas liking refers to an immediate qualitative, hedonic evaluation of a product without a direct comparison with other products (Mela 2001). In the present study, both children’s preferences and likings was examined by the use of ranking and rating tests. The ranking test shows that no conclusion can be drawn on the influence of increased fruit content in AMPs on children’s preferences. When examining the results of children’s average liking scores, it seems that increasing the fruit content has a significant effect on liking of both HF and LF. Table 4 shows a significant increase in liking when fruit content was increased from 10 to 15%. AMPs with 15–20% fruit are liked significant over AMPs with 5–10% fruit regarding both LF and HF. The same pattern is seen for wanting.

In summary, the ranking and the rating test show different results. However, the two methods evaluate two different measures, liking and preference, respectively. The ranking test provides information on which of the products the children prefer least and most as a ranking test forces children to make a rank order of the products. A test of children’s preferences does not necessarily provide information about children actually liking the products. In contrast, the rating method gives children the possibility to state the degree of how much they like the products. It is essential to be aware of this difference.

**Children’s Liking and Wanting**

Multivariate data analysis of the rating data on liking is an appropriate way of analyzing such consumer data aiming to segment the children according to their liking and wanting. The biplot in Fig. 2 shows the distribution of the eight different AMP samples varying in fat and fruit content, and liking and wanting. The AMP samples are the scores (mode 1), and liking and wanting are the loadings (mode 3). The first component explains 24.5% of the variation and clearly spans the samples in relation to fruit content. The samples containing 5% fruit (both HF and LF) are situated in the left side of the

### TABLE 3. RANK SUMS FOR PREFERENCE AND PERCEPTION OF SOURNESS OF TWO DIFFERENT ACIDIFIED MILK PRODUCTS VARYING IN FAT AND FRUIT CONTENT

<table>
<thead>
<tr>
<th>Fat content</th>
<th>HF</th>
<th>LF</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rank sum-preference</td>
<td>♀ 218a</td>
<td>225a</td>
<td>257a</td>
<td>260a</td>
<td>216a</td>
<td>232ab</td>
<td>244ab</td>
<td>265b</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>♂ 308a</td>
<td>302a</td>
<td>323a</td>
<td>287a</td>
<td>294a</td>
<td>286a</td>
<td>332a</td>
<td>313a</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rank sum-sourness</td>
<td>♀ 231a</td>
<td>232a</td>
<td>239a</td>
<td>258a</td>
<td>242a</td>
<td>231a</td>
<td>230a</td>
<td>257a</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>♂ 277a</td>
<td>306ab</td>
<td>306ab</td>
<td>335b</td>
<td>311a</td>
<td>303a</td>
<td>285a</td>
<td>322a</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The statistical significances refer to the samples within high fat (HF) or within low fat (LF) for either boys or girls.

### TABLE 4. MEAN RATING AND WANTING OF TWO DIFFERENT ACIDIFIED MILK PRODUCTS VARYING IN FAT AND FRUIT CONTENT

<table>
<thead>
<tr>
<th>Fat content</th>
<th>LF</th>
<th>HF</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
<th>5%</th>
<th>10%</th>
<th>15%</th>
<th>20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liking</td>
<td>3.33a</td>
<td>3.39a</td>
<td>3.65b</td>
<td>3.59b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.39a</td>
<td>3.40a</td>
<td>3.69b</td>
<td>3.67b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wanting</td>
<td>2.60a</td>
<td>2.68a</td>
<td>2.89b</td>
<td>2.81b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2.73a</td>
<td>2.77a</td>
<td>3.00b</td>
<td>2.84a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The statistical significances refer to the fruit content within high fat (HF) and low fat (LF). Significant differences between samples within each attributes are given by different letters.

**FIG. 2. BIPLOT FROM PARAFAC ANALYSIS**

Biplot from PARAFAC model where acidified milk product (AMP) samples (HF_5–20% and LF_5–20%) are the scores and liking and wanting are the loadings (mode 3). The first component explains 24.5% of the variation and clearly spans the samples in relation to fruit content. The samples containing 5% fruit (both HF and LF) are situated in the left side of the

The second component, explaining 12% of the variation, obviously distinguishes the difference in fat content between the AMPs with samples containing a high fat level placed in the upper left quadrant of the biplot and samples with low fat content situated in the lower left quadrant of the biplot. However, this separation is only visible for the AMP samples with 5 and 10% fruit. When 15 and 20% fruit is added to the AMP, there is no separation between the high and low fat products, indicating that a high fruit level in AMP has a masking effect on the fat content.

Liking and wanting are situated very close to the AMP samples (both HF and LF) with 15 and 20% fruit, which emphasizes that a very high correlation among liking, wanting and AMP samples with high fruit content exists. This result clearly shows that children both like and want AMPs with fruit content that is higher than the products currently available on the Danish marked being an AMP with, on average, 8% fruit. The results also indicate that fat content has no influence on liking and wanting when a high amount of fruit is added, but when AMPs only contains 5 and 10% fruit, the HF is closer correlated to liking and wanting than LF. In summary, fat has an influence on liking and wanting when the AMP contains a low amount of fruit, whereas fat content has no influence on liking and wanting when AMPs contain a high content of fruit. The close correlation between HF and liking and wanting in the case of AMPs with low fruit content may be a result of the higher degree of satiety associated with high-fat products compared with low-fat products.

Figure 3 illustrates the distribution of the children (mode 2) in the loading plot. There are more children situated in the right quadrants of the loading plot, especially in the upper right quadrant, where liking and wanting, and the AMPs with 15 and 20% fruit content are situated. This highlights a large segment of children liking and wanting AMPs with high fruit content.

**Segmentation of Children Based on Rating Data**

Based on a visual segmentation, the loading plot (Fig. 3) was split into four segments (A, B, C and D) according to the children’s position in the four quadrants. The segments are established on the assumption that in each quadrant, liking and wanting of a specific variation of AMP is found. Helgesen *et al.* (1997) also did visual segmentation of internal preference mapping on more than 100 consumers and found that visual segmentation and cluster analysis gave fairly the “same” subgroups. On the basis of their results, they concluded that in cases with relatively small numbers of consumers, both cluster analysis and visual segmentation of the plots identified more or less the same segmentation pattern (Helgesen *et al.* 1997). From the segmentation in the present study, we want to ascertain whether it is possible to characterize the children within the four segments and gain insight into whether gender or specific age groups might be predictable of different product preferences. This was done by $\chi^2$ statistics for similarities among the segments. A description of each segment according to gender and age is shown in Table 5.

Figure 3 illustrates the segments based on the four quadrants. Children in quadrant A like HF_5% and HF_10%, children in quadrant B like HF and LF with 20% fruit and HF_15%, children in quadrant C like LF with 5% fruit and children in quadrant D like LF with 10 and 15% fruit. The results of this analysis show that quadrant A contains more children from the age group 13–14 years than statistically expected, which implies that more children from the oldest age group like and want AMPs containing a high fat content and a low fruit content compared with the youngest age group. This fact substantiates the importance of making strategies for changing children’s preferences in a healthier direction as early as possible. When children are getting older, the parental influence on children’s dietary intake decreases, and peer influence increases.
Segment C comprise more girls than statistically expected, indicating that more girls than boys like and want AMP with a low fat and fruit content. This does not mean that girls like AMPs with low fruit content more than they like AMPs with high fruit content. It is important to be aware that the chi-squared test and PARAFAC analysis test data from two different angles. The PARAFAC method is based on the samples and examines how the children are distributed. The chi-squared test characterizes the segments, e.g., children in segment C is, to a greater extent, composed of more girls than boys. The overall result is still that children, both girls and boys, like and want AMPs with high fruit content as segment B is the largest of the four segments. It enrolls more than 70 children. The liking of AMPs with high fruit content is further supported by the multiple ranking tests, which slightly show that children prefer AMPs with high fruit content. It is obvious that in the present study, the rating method, coupled with multivariate data analysis, displays more difference in liking of the various AMPs than elucidated by the ranking method. However, knowledge of the different segments of children is a strong tool that can be used to explore how different products appeal to children of different ages or genders. Such information is of special interest as it might enable product developers to “tailor-make” products to specific segments of children.

Difference in Preference and Liking between Segments

In consumer studies, it is of high importance to examine the individual consumers and not only on the group as a whole. For that reason, Friedman’s analysis of ranks was repeated on the four segments, based on the visual segmentation of the loading plot (Fig. 3), as these may have ranked the AMPs differently. Figure 4 shows the pattern in the four segments and, as hypothesized, there is a large variation in how the different segments rank the products.

In general, large differences in how the AMPs with varying fruit content are preferred exist between the segments. Segments A and C rank AMPs with 5% fruit significantly higher than segments B and D. In relation to AMPs with 10% fruit, segment C has a higher ranking than segment B and D. Segment A also prefers HF10% more than segments B and D. Segments B and D generally rank AMPs with 15% fruit higher than segments A and C, which is also the case with AMPs containing 20% fruit. This clearly illustrates that the results from the PARAFAC analysis support the multiple ranking as both analyses elucidate the existence of segments among the children.

The existence of the four segments found in the PARAFAC analysis is further supported by examining the average liking and wanting scores of the four segments. Table 6 shows that children in segments A and C significantly like and want AMPs with low fruit content. Even though the children did not compare HF and LF products, it is obvious that children in segment A rate HF5-10% higher in liking and wanting than LF5-10%, and segment C rated LF5-10% highest. This difference is also seen in Figs. 2 and 3. However, when fruit content increases to 15 and 20%, it seems that segment C likes LF whereas segment A likes HF, indicating that an increased fruit content influences the perception of the products according to the children in segments A and C. Segments B and D like and want AMPs with high fruit content significantly over AMPs with low fruit content.

The analysis of average liking and wanting scores of the four different segments supports the results from the PARAFAC analysis.

Correlation between Liking and Wanting

In the present study, both liking and wanting for AMP were measured as it has been suggested that both liking and wanting play an important interdependent role in food
choice and consumption in adults (Mela 2006; Finlayson et al. 2007). Kildegaard et al. (2011) have previously shown a high correlation between children’s liking and wanting for apple juice and fruit drink, which was also observed in this study. The biplot (Fig. 2) from the PARAFAC analysis shows a high correlation between liking and wanting as the two variables are closely situated in the biplot. Furthermore Fig. 5 shows a positive correlation between liking and wanting for the four AMPs varying in fat and fruit contents. However, it is obvious that wanting scores are significantly lower than the liking scores ($P < 0.001$).

A limitation of the present study is that the hedonic scales used for rating liking and wanting were very similar and only short time frame elapsed between the evaluations of liking and wanting. This could have biased the results and caused the high similarity in liking and wanting. However, it does not explain the gap between liking and wanting.

It has previously been suggested that wanting depends on contextual factors, e.g., the context in which a particular food is served and the perceived appropriateness of consumption of particular foods (Mela 2006). In Denmark, AMPs are normally eaten for breakfast, but in the present study, it was evaluated between 10:00 and 12:00 a.m., indicating that the AMPs were eaten in a different context than normal. The appropriateness of the consumption of AMP in the middle of the day was abnormal, which probably caused the lower wanting. A hypothesis could be that liking determines the range of acceptable food, whereas the type and the amount of food eaten is dominated by wanting. This, however, needs to be tested in future research.

**CONCLUSION**

Increases in children’s preferences, liking and wanting for AMPs with stepwise increased fruit content were determined by two sensory methodologies: ranking and rating. The high liking and wanting for AMP with high fruit content gives the food industry an option to produce new healthy food products for children without loss in children’s liking. The masking effect of higher fruit content also gives some future possibilities for producing low fat food products with increased fruit content. Rating data analyzed by PARAFAC illustrated a large and informative segmentation in children’s liking and wanting for high fruit loads in AMP. This segmentation was further used for analyzing the ranking data, which hereby gave more information about preference data than compared with the analysis of all children. When analyzing, all children’s differences in sourness perception could not explain the differences in preferences.

A high correlation between liking and wanting was revealed as hypothesized. However, wanting scores were significantly lower than liking scores, which may be caused by contextual factors. It remains to be determined how these low wanting scores affect children’s food consumption, and sensory testing with children in future research should focus not only on liking but rather on liking and wanting.

### TABLE 6. MEAN RATING AND WANTING FOR HIGH FAT (HF) AND LOW FAT (LF) OF CHILDREN SEGMENTED INTO FOUR SEGMENTS (A, B, C, D)

<table>
<thead>
<tr>
<th>Segment</th>
<th>Fat content</th>
<th>Liking</th>
<th>Wanting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fruit content</td>
<td>5%</td>
<td>10%</td>
</tr>
<tr>
<td>A</td>
<td>LF</td>
<td>3.67a</td>
<td>3.17b</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>4.52a</td>
<td>4.22b</td>
</tr>
<tr>
<td>B</td>
<td>LF</td>
<td>2.51a</td>
<td>3.10b</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>2.83a</td>
<td>3.28b</td>
</tr>
<tr>
<td>C</td>
<td>LF</td>
<td>4.24a</td>
<td>3.71b</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>4.00a</td>
<td>3.60b</td>
</tr>
<tr>
<td>D</td>
<td>LF</td>
<td>3.51a</td>
<td>3.78ab</td>
</tr>
<tr>
<td></td>
<td>HF</td>
<td>2.69a</td>
<td>2.67a</td>
</tr>
</tbody>
</table>

The statistical significances refer to the samples within HF and LF. Significant differences between samples within each attribute are given by different letters. See further details about samples in Table 2.

**FIG. 5. MEAN RATINGS OF LIKING AND WANTING FOR HF AND LF**

Mean ratings ($n = 204$ children) of liking ($\bullet$ = LF, $\circ$ = HF) and wanting $\square$ = LF, $\star$ = HF of acidified milk products with stepwise changed fruit content. See further details about the samples in Table 2.
ACKNOWLEDGMENTS

The Danish Agency for Science, Technology and Innovation is greatly acknowledged for financial support to the project (FeSu-project: Step by step changing of children’s preferences for healthier foods, J.nr. 3304-FSE-06–0504). Thanks are due to Rynkeby Foods A/S, Arla Foods amba and Dairy Foods A/S for delivering the products and to Mette Pedersen, Lone Storm and Lone Borum for technical assistance.

REFERENCES


H. KILDEGAARD, M.M. LØKKE and A.K. THYBO

CHILDREN’S LIKING AND WANTING
Abstract: This study aimed to examine the development in liking of fermented milk products (FMP) as affected by a stepwise increase in designed complexity during repeated exposure. Likewise, the study aimed at elucidating sensory attributes that characterise children’s liking by using Flash Profile. In total, 197 children rated their liking for six FMPs that differed stepwise in designed complexity by adding one component per step: A) FMP, B) + pear pieces, C) + mango puree, D) + fibres, E) + mango pieces, F) + flavours. The results showed that liking for a FMP with a high level of designed complexity increased during exposure, whereas exposure to FMPs with low levels of designed complexity resulted in decreased liking and increased boredom towards the product. High liking for FMPs was positively correlated to sweetness, creaminess, high intensity of fruit and perfumed aftertaste. Finally, flavours in the present concentration seem to mask addition of fibres and fruit to FMP.
Dear Editor

Enclosed is a paper, entitled “Effects of Repeated Exposure to Fermented Milk Products with a Stepwise Increase in Designed Complexity on Children’s Liking”. Please accept it as a candidate for publication in Food Quality and Preference.

Corresponding author of the attached manuscript is: Heidi Kildegaard

Contact address:

Aarhus University, Department of Food Science
Kirstinebjergvej 10
DK-5792 Aarslev
Tel.: +45 8999 3413
Fax: +45 8999 3495
Email: Heidi.kildegaard@agrsci.dk

I look forward to hearing from you.

Yours sincerely

Heidi Kildegaard, Ph.D. student
• Repeated exposure to fermented milk products, with a stepwise increased level of designed complexity, increases children’s liking for the complex FMPs.

• Flash Profile appears to be a fast, convenient method to elucidate sensory attributes important for children’s liking.

• Flavours are drivers for liking
Effects of Repeated Exposure to Fermented Milk Products with a Stepwise Increase in Designed Complexity on Children´s Liking

Kildegaard, Heidi\textsuperscript{a}, Delholm, Christian\textsuperscript{b} and Thybo, Anette K\textsuperscript{a}\textsuperscript{*}

\textsuperscript{a} Dept. of Food Science, Faculty of Agricultural Sciences, Aarhus University, DK-5792 Aarslev, Denmark

\textsuperscript{b} Department of Food Science, Faculty of Life Sciences, University of Copenhagen, Rolighedsvej 30, 1958 Frederiksberg C, Denmark

\textsuperscript{*}Corresponding author: Telephone: +45 89 99 34 05. Fax: +45 89 99 34 95. Email: anette.thybo@agrsci.dk

Abstract

This study aimed to examine the development in liking of fermented milk products (FMP) as affected by a stepwise increase in designed complexity during repeated exposure. Likewise, the study aimed at elucidating sensory attributes that characterise children’s liking by using Flash Profile. In total, 197 children rated their liking for six FMPs that differed stepwise in designed complexity by adding one component per step: A) FMP, B) + pear pieces, C) + mango puree, D) + fibres, E) + mango pieces, F) + flavours. The results showed that liking for a FMP with a high level of designed complexity increased during exposure, whereas exposure to FMPs with low levels of designed complexity resulted in decreased liking and increased boredom towards the product. High liking for FMPs was positively correlated to sweetness, creaminess, high intensity of fruit and perfumed aftertaste. Finally, flavours in the present concentration seem to mask addition of fibres and fruit to FMP.
Keywords Children, liking, repeated exposure, complexity, fermented milk product, Flash Profile.
1. Introduction

There has been particular interest in increasing fruit, vegetable and fibre intake among children and adolescents as early intervention is likely to maximise health benefits (Perry et al., 1998).

Furthermore, eating habits in childhood are strongly predictive of those in adulthood (Lake, Adamson, Craigie, Rugg-Gunn, & Mathers, 2009). In studies with children, liking has been shown to be highly predictive of actual intake (Gibson, Wardle, & Watts, 1998), and parents often state dislike as the primary explanation for children’s low intake of fruit, vegetables and fibres. If dislike represents an important barrier to consumption of healthy foods, interventions aimed at modifying children’s liking may play an important role. A growing body of research suggests that liking for foods can be changed during repeated exposures, showing either an increase in liking, a sustained liking or a decrease in liking (Levy, MacRae, & Koester, 2006; Liem & de Graaf, 2004; Sullivan & Birch, 1990; Sullivan & Birch, 1994; Wardle, Herrera, Cooke, & Gibson, 2003). The changes in liking appear to depend on certain sensory properties of foods (Weijzen, Zandstra, Alfieri, & de Graaf, 2008). However, it is not clear, which sensory properties of the food that drive liking. One study indicated that the level of taste intensity of the food might influence liking over repeated exposure (Vickers & Holton, 1998). The study showed that iced teas with low taste intensity were liked over iced teas with high taste intensity. Decreased liking for intense stimuli during repeated exposure was also found by Chung & Vickers, 2007 and Zandstra, de Graaf, Mela, & Van Staveren, 2000. Others have argued that a high novelty foods gains an increase in liking due to repeated exposure (Sullivan & Birch, 1990).

Changes in liking after repeated exposures may also be related to the arousal potential and the perceived complexity of the food. Lévy et al., 2006, found that liking for complex orange drinks with a high arousal potential increased with repeated exposure, while the same effect was not seen after repeated exposure to simple orange drinks. Similar results were found by Weijzen et al., 2008,
and Reverdy, Schlich, Koster, Ginon, & Lange, 2010. However, Porcherot and Issanchou (1998) were not able to support the relation between perceived complexity and liking after repeated exposure in their study with flavoured crackers.

To the authors’ knowledge, no consensus about how to measure the concept ‘complexity’ exists. In one study, the level of complexity in orange drinks was adjusted by adding small quantities of other flavours, and three sensory attribute acronyms were defined to measure perceived complexity. These were Simple (made with a single flavour) > Elaborated (composed of a mixture of many flavours), Straight (direct, firm) > Confusing (obscure, difficult to describe) and Homogeneous (the flavours are melted together) > Shattered (certain flavours clearly detach themselves from the whole) (Levy et al., 2006). Weijzen et al., 2008, also selected three attributes to measure complexity; ‘complex’, ‘number of ingredients’ and ‘difficulty to describe’, indicating that the concept ‘complexity’ consists of several dimensions.

The theory behind the concept of complexity and liking is well described. An inverted U-form relationship between the arousal level and liking was suggested of Berlyne, 1970. In this theory, the arousal level of a stimulus is a combination of intensity, complexity and novelty, and it determined the degree of liking. The inverted U-curve indicated that for each individual subject, there is an optimal arousal level below and above which, stimuli are liked less. This optimal arousal level may differ among subjects, and it depends on learning and experience. Dember and Earl (1957) explained this learning effect by assuming that repeated exposure to a stimulus above the optimal arousing level increased the individual’s optimal arousal level. As a result, the arousal of a stimulus in the same category decreased, and liking of the stimulus increased. Oppositely, repeated exposure to a stimulus with a lower than optimal arousal level will not affect the optimal arousal level, which results in boredom and a decreased liking. Based on the arousal theory of Berlyne, we hypothesize
that repeated exposure of a food product with a high degree of designed complexity will increase
children´s liking.

The elucidation of the factors that drive children´s liking of foods is very relevant for the study of
children´s liking behaviour. A classical sensory profile will help elucidating these factors. However,
in the case of sensory profiling, the importance of the different attributes in the overall perception
by the assessors is not known and in order to take individual perceptions into consideration, the fast
sensory method ‘Flash Profile’ was developed (Delarue & Sieffermann, 2004). Flash Profile is
attractive, because the assessors make their own list of attributes, by which more individual
attributes are taken into consideration. The method is an original combination of free-choice
attribute selection and a ranking method based on simultaneous presentation of the whole product
set. Moreover, it does not demand a training stage, thus making it a fast sensory methodology. Flash
Profile has previously been used to describe sensory attributes of a set of red fruit jams, yoghurts
and bread (Albert, Varela, Salvador, Hough, & Fiszman, 2011; Dairou & Sieffermann, 2002;
Delarue & Sieffermann, 2004). It proved to be satisfactory as compared to a conventional profile
which makes it a potentially useful tool for fast sensory analyses. Based on this, it is hypothesized
that relevant sensory attributes can be defined using Flash Profile as a fast method, which in
combination with children´s liking data can explain the sensory drivers for children´s liking of six FMPs.

In the present study, the aims are to:

1. examine the effect of repeated exposure on children´s liking for FMPs with a stepwise
   increased level of designed complexity
2. elucidate the sensory characteristics for children´s liking for the six FMPs varying in
   complexity by using Flash Profile
This knowledge will form the basis for further changes in food composition and product
development, taking both liking and healthiness into consideration.

2. Materials

2.1 Children

A Danish public school was invited to participate in a study on the effect of repeated exposure to
FMPs with a stepwise increase in designed complexity on children’s liking. In total, 220 children
(95 ♀ and 125 ♂) aged 9-14 years old (mean age=12.3 years) agreed to participate in the study, and
197 children (83 ♀/113 ♂) completed the study determined by a full participation. Children with
more than two missing exposures were excluded from the study.

Permission to execute the experiments with full cooperation of the teachers was obtained from the
responsible authorities, and the parents of all participating children gave their written consent.
The children’s participation in the test was voluntary. The study was exempted from the need of
formal ethical approval according to the rules of the Danish ethical committee, since it did not
involve any physical interference with the children.

2.2 Products

The products used in the present study were designed FMPs varying stepwise in designed
complexity. The arousal theory of Berlyne 1970, which was a combination of taste intensity, food
complexity and novelty, was used to generate the six levels of designed complexity. In total, six
FMPs were developed starting with the least complex FMP, sample A, which was a slightly
modified version of a well-known commercial FMP, to sample F, which is a very complex FMP
with high degrees of intensity, complexity and novelty (Table 1).
The basic FMP used in the development of the six samples was composed of milk and milk proteins (80% casein and 20% whey) and contained 3 g protein pr. 100 g FMP. The FMPs were homogenized, pasteurised and acidified with milk acid cultures and cultures of L. Acidophilus. The FMPs were provided by a Danish dairy company, Arla Foods amba DK-8260 Viby, Denmark.

The basic FMP was added six various marmalades resulting in the six samples (sample A-F) with a stepwise increase in designed complexity (Table 1). The composition of the marmalades and the dosage of the marmalades added to the basic FMP result in similar FMPs except from the stepwise changes in complexity. The recipes of the marmalades are shown in Table 2. The dosage of the marmalades added to the basic FMP differed from 11 and 24%. All marmalades were supplied by a Danish supplier of fruit puree, Dairy Fruits A/S DK-5260 Odense, Denmark.

The saccarose concentration in all FMPs was constant and reduced by 25% compared to commercial FMPs resulting in a saccarose content at 5%. A commercial FMP with fruit typically contains 7.3% sugar in Denmark. Due to the low storability of the non-pasteurised marmalades, the samples were mixed each day. The samples varied in colour; A and B being light yellow, and C-F being darker yellow. Portions of 100 ml of the FMPs were stored in transparent containers with lids.
Each container was coded with a random 3-digit number and stored at 5°C until used. Before serving, the FMPs were kept 30 min at room temperature resulting in a serving temperature at approximately 10°C.

2.3 Experimental design

The study was a randomised, controlled intervention study with taste exposure, and it consisted of two parts; a preliminary study and the intervention part including repeated exposure at schools. Simultaneously, a sensory panel preformed Flash Profile.

2.3.1. Preliminary study

The preliminary study served both as an introduction to the repeated exposure that occurred two weeks later, and a preliminary rating test of liking of the six FMPs. This procedure was chosen to ensure that liking scores were low enough at baseline to avoid a ceiling effect and to allow an increase in liking during exposure. First, a trained instructor introduced the repeated exposure in details to the children without revealing the purpose of the study. Moreover, the children’s understanding of the hedonic smiley scale was established by showing and explaining the meaning of the pictorial faces. The 7-point hedonic smiley scale ranged from 1 point = super bad (sad face) to 7 point= super good (smiling face) (Chen, Resurreccion, & Paguio, 1996). The seven pictorial faces represented 1) super bad, 2) really bad, 3) bad 4) maybe good or maybe bad 5) good 6) really good 7) super good. The applied procedure has previously been used and validated on children (Kimmel, Sigmangrant, & Guinard, 1994). Second, children’s liking for the six FMPs was determined. In the rating test, the children were served a warm-up sample, which was a commercial FMP with banana and pear taste, and then the six FMPs with a stepwise increased, designed complexity. The warm-up sample was given to
prepare the taste buds for evaluation of FMPs. The samples were served in a tray with a teaspoon. The placement of the six samples in the tray was random. After tasting a minimum of three tea spoons of the warm-up sample, the children were asked to taste and rate the six different FMPs according to liking on the hedonic smiley scale. The amount of the samples which each child consumed was voluntary. Through the rating test, the children were allowed to ask questions to the instructor, if they did not understand the instructions, they were given. Except for asking clarifying questions, the children were told to remain silent during the test to avoid peer influence and thereby assuring unbiased opinions (Popper & Kroll, 2005). The teachers were asked to encourage all children to eat a snack in the break before the rating test to ensure that they were not hungry. Large differences in hunger status could bias the result of the rating test.

2.3.2 Repeated exposure

Before starting the intervention, the children performed the first rating test of liking. The procedure of the rating test is described above. After completing the rating test, the children were randomly assigned to one of four experimental groups. For further details of the four experimental groups, see Table 3.

Table 3

The groups were formed across grades to ensure representation of all age groups in each of the experimental groups. The children participated in the repeated exposure study for 14 days, only separated by weekends (10 exposures). The exposure occurred each day from 10-12 a.m. Instructors visited the classrooms and served the sample A, D or F for the exposure groups, respectively. The children were seated at
their tables during the exposure period. After 10 days of repeated exposure to the specific samples, the children performed a second rating test of liking to examine the development in liking during the exposure period.

2.3.3 Flash Profile

A trained panel performed the Flash Profile. The panel comprised 11 assessors (9♀, 2♂). They were not trained to the evaluation of FMP, yet they had prior experience in descriptive evaluation of FMP.

*The assessment procedure.* To introduce the concept of Flash Profile, the assessors were given a brief outline of the procedures.

*Step 1:* The assessors were presented with a warm-up sample and the six FMPs, and they were asked to list the sensory attributes that described the differences between the six samples. Each assessor created their own vocabulary of attributes. To assist in the development of the vocabulary, the assessors were instructed to group terms for appearance (A), texture (TX) and taste (TA) separately. They were instructed to rinse their mouth between samples. This session was individual and lasted approximately 30 min.

*Step 2:* Each assessor compared their own list of attributes with the list from the other assessors to ensure that they did not forget important sensory dimensions. Hereafter the assessors chose their definitive list of attributes with a maximum of 20 terms. This session lasted approximately 20 min.

*Step 3-4:* The assessors made an evaluation of the six FMPs according to their list of attributes. All samples were presented in a randomised order to the assessors, who were asked to rank each sample for each attribute from their list on an unstructured 15 cm line scale. The evaluation sessions lasted approximately 1 hour, and evaluations were performed in duplicates.
2.4 Data analysis

Data from the Flash Profile were treated by a Multiple Factor Analysis (MFA) (Escofier & Pages, 1994). This kind of multivariate analysis allows investigating differences among products by taking several variables into account simultaneously. MFA is a global factor analysis where groups of variables can be weighted so as to balance their influences. If variables are numeric, the first step consists of performing a PCA per group of variables. Then each variable is multiplied by the inverse of the first eigenvalue issued from the corresponding factor analysis. The second step consists in performing a PCA on the resulting data, which yields a configuration taking into account all the weighed variables. In the present study, 11 groups corresponding to each assessor’s dataset were defined. The MFA was performed using the statistical software R version 2.12.1 (Ihaka & Gentleman, 1996).

Eight sensory attributes that are highly relevant for the description of the variation between the six FMPs were selected from the MFA. A Spider plot of the attributes was created on mean values to investigate the actual differences in the attributes between the six FMPs. These analyses were performed in Microsoft Office Excel 2007 (Addinsoft, Paris). To investigate the relationship between eight selected sensory attributes and children’s liking for the six FMPs, a Principal Component Analysis (PCA) was performed using SIMCA-P software (version 12.0.1; Umetrics AB). Full cross validation was used as validation criterion (Martens & Naes, 1989).

The differences between mean values of liking scores from the two rating tests were tested using a student’s t-test. Statistical analyses were performed the statistical software R version 2.12.1 (Vienna, Austria. 2010). Statistical significance was defined at p<0.05.
3. Results

3.1 Preliminary study
The results from the preliminary study showed high rating scores for the six FMPs, which indicated that the sample was highly liked, and that a ceiling effect was imminent. This resulted in a reformulation of the recipes of the FMPs, where saccarose concentration was further reduced and a higher concentration of both pear and mango pieces were added.

3.2 Children´s liking of the six FMPs at baseline
When observing the mean liking scores for all children, there was an obvious difference in liking between the six FMPs pre-exposure (Fig. 1). Sample A, the least complex FMP, obtained the significantly lowest mean liking score followed by B, E and D. It was observed that liking was significantly increased when increasing the level of complexity going from sample A to C. Increasing the level of complexity from sample C to E significantly decreased liking, followed by an increase in liking for the most complex FMP (sample F). The semi-complex sample C and the most complex sample F were liked significantly over the other FMPs.

Fig. 1

3.3 Development in liking during repeated exposure
Comparing data on liking from the initial ratings showed that there were no significant differences in liking between the six FMPs for any of the experimental groups (n=4) (Fig. 2). However, during the exposure period, the development in liking for the FMPs differed between the four groups. In Gr. 1, which was exposed to the least complex FMP (sample A), it seemed that liking for sample A was increased after 10 days of repeated exposure. Yet, the increase was not significant ($p=0.09$). A tendency to a decrease in liking during exposure was seen for the other five FMP samples, but the
decreases were only significant for sample D (p=0.03). In Gr. 2, which was exposed to the medium complex FMP (sample D), a slight increase in liking was seen for the most complex FMP (sample F) post exposure, but the increase was not significant (p=0.2). A significant decrease in liking was seen for sample B (p=0.01). In Gr. 3 being exposed to the most complex FMP (sample F), a significant increase in liking after 10 exposures was seen for sample F (p=0.02), and a significant decrease in liking was observed for the least complex samples A-C (p<0.001). Gr. 3 was therefore the only group showing a significant increase in liking for the complex FMP during repeated exposure. The control group showed no significant changes in liking post exposure.

Fig. 2

3.4 Sensory attributes elucidated by Flash Profile
During the first session of Flash Profile, each assessor created between 13 and 22 terms. In the second session, each assessor selected a definitive list of attributes with a maximum of 20 attributes. The lists contained between 14 and 20 terms, and in total 178 terms were obtained for the total panel. The results from the MFA of the total set of Flash Profile data show that the first dimension in the individual factor map explains 63% of the variation, and it opposes samples A and B, the two least complex FMPs, to the other more complex samples C-F (Fig. 3). The second dimension explains 15% of the variation and opposes sample F to samples C, D, E.

Fig. 3

The position of the sensory attributes is seen in Figure 4. The figure allows visualisation of the sensory attributes. However, due to a large number of attributes, the correlation circle could not be represented with all the attributes. The first dimension separates the attributes; sour taste, FMP
taste, fresh fruit taste, astringency and cream colour from sweet taste, creamy taste and creamy
texture, exotic fruit taste, high intensity of fruit, large fruit pieces and yellow colour. The second
dimension separates canned fruit taste from perfumed taste, artificial taste, complex taste and
pungent taste. The plot shows a high agreement between the assessors for most of the attributes as
clusters of assessor’s scores for the attributes are found.

Based on the results in the correlation circle, the attributes being most relevant for the description of
the variation between the six FMPs were selected. The basis for the selection was that the attributes
should span both the 1st and 2nd dimension, they should be evaluated by most of the assessors, and
they should be evaluated in an equal way. Eight attributes were selected (Fig. 5).

Sample A was characterised as being very sour, light yellow, thin and non creamy and low in
intensity of fruit compared to sample C-F. Sample B had almost the same sensory profile as sample
A with a slightly higher intensity of fruit (small pieces of pear) than sample A and with a texture
perceived as more thick and creamy. A large change in the sensory profile was observed between
samples A and B and samples C-F. Sample C was added mango puree, which induced an increase
in yellowness in samples C-F. Moreover, sour taste decreased significantly, when mango was
added, even though the sugar concentration was equal. The sensory profile of samples C-F was
quite similar, as they had a more creamy texture and were more sweet than samples A and B.
However, in relation to thickness, samples D-F scored higher than C, and differences were also
observed according to intensity of fruit content, perfumed taste and yellowness. Sample F had the
highest intensity of the attribute ‘perfumed taste’ compared to the other samples.
Figure 5 shows that sample F, the most complex FMP, was highest in intensity in many sensory attributes, which indicated that a high intensity of the sensory attributes equals a high level of designed complexity.

3.5 Relationship between sensory attributes and children’s liking of the six FMPs

Relationships between the eight selected sensory attributes and children’s liking scores for the six FMPs were studied by PCA. Eighty-four percent of the variation was explained by one significant principal component (PC1), while 6% of the variation was explained by PC2. The plot illustrates a high relationship between liking and high intensity in perfumed taste, fruit, sweet taste and low intensity in sour taste. Fig. 6 confirms that sample F is the most liked FMP, and that sample A and B are the least liked products.

4 Discussion

A large body of research has shown that repeated exposure can increase children’s liking (Birch & Marlin, 1982; Levy et al., 2006; Sullivan & Birch, 1990; Sullivan & Birch, 1994; Wardle et al., 2003). These studies, including both infants, children and adults, have provided strong support for the efficacy of exposure, demonstrating that tasting a food or a drink often increases liking for it. However, it should be noted that most of these studies were performed on many different foods which were quite different from each other or foods that were novel to the subject (Cooke, 2007). The high focus on individual products makes it difficult to determine which specific product properties or sensory attributes (e.g. appearance, flavour, texture and mouth feel) are important for a change in liking after repeated exposure. Previous results show that liking for some products
increases after repeated exposure, whereas liking for other products remains stable or decreases after repeated exposure. Liem and de Graaf (2004) were one of the few who actually studied the effect of exposure with a sweet and a sour lemonade in order to understand the effect of sensory properties (sweet and sour taste) on liking after repeated exposure. They found that repeated exposure (8 consecutive days) to a sweet lemonade increased children’s liking for this lemonade. In contrast, repeated exposure to a sour lemonade, which was initially liked to the same extent as the sweet lemonade, remained stable in liking. In contrast to many of the studies mentioned above, the present study on repeated exposure goes beyond the focus on products as the product variation was designed by altering the complexity and the sensory properties stepwise. The large diversity in sensory properties was documented by the results from the Flash Profile (Fig. 4 and 5). The results proved that it was possible to significantly increase children’s liking by repeated exposure, when children were exposed to the most complex FMP with five added stimuli (sample F).

The increase in liking for the most complex FMP (sample F) observed in Gr. 3 after repeated exposure was in full accordance with the theory-based hypotheses regarding the role of stimulus complexity on changes of liking after repeated exposure. Furthermore, repeated exposure to the simple FMPs (sample A-C) with only 1 or 2 stimuli added did not affect children’s optimal arousal level; resulting in a decreased liking and probably in boredom. Similar results were observed by Reverdy et al., 2010, who found that children increased their liking for mashed potatoes and compotes with high arousal potential, whereas liking was reduced for mashed potatoes with a lower arousal potential. Lévy et al., 2006, found that adults’ liking for complex orange drinks with a high arousal potential increased with repeated exposure, while the same effect was not demonstrated after repeated exposure to simple orange drink. Oppositely, results from Porcherot and Issanchou (1998) did not support the theory as liking for complex crackers did not increase during repeated exposure. Nevertheless, our study supports the findings of others that exposure has an effect on the
liking of more complex products. Dember and Earl’s (1957) theory states that exposure to products with a level of complexity that increases the individual’s optimal arousal level has a positive effect on liking for such products and has a negative effect on liking for simple products. However, this theory could not be tested directly, as the present study was not designed to predict the position of the arousal potential of the FMPs relative to the optimal arousal level. Hence, more studies of the relation between children’s optimal arousal level and food acceptance are needed.

Sample F, which was the only sample where liking significantly increased during repeated exposure, was liked over the other samples except from sample C (Fig. 1). Thus, the possibility that the increased liking for the complex sample F was due to initial high liking rather than due to the level of designed complexity cannot be excluded. An early study showed that an initial high liking for foods slowed the development of boredom (Schutz & Pilgrim, 1958). In contrast, more recent studies demonstrated the opposite, i.e., that highly liked foods dropped in liking, while moderately liked foods did not (Chung & Vickers, 2007; Hetherington, Pirie, & Nabb, 2002). The latter findings support the statement that the increased liking for sample F in the present study, being an FMP with five added stimuli, was not due to a high initial liking. The sensory data support the perception of an increased complexity, as sample F has a high intensity in many sensory properties.

A tendency to an increase in liking for the most complex (sample F) was also observed in Gr. 2 (Fig. 2). This increase was not seen in Gr.1. During repeated exposure, Gr. 2 was exposed to the medium complex FMP (sample D), characterised as having a high intensity of thickness, creaminess and sweetness, while Gr. 1 was exposed to the most simple FMP (sample A), having low intensities in most of the sensory attributes. This tendency further supports the theory of Dember and Earl (1957) indicating that higher degrees of complexity and novelty affect an increase in liking during repeated exposure.
The fact that the present results are in accordance with the theory of complexity at least for the most complex product supports the validity of the effects of complexity on liking. Yet, future studies that aim to test these effects of complexity on children’s liking should address on how to measure perceived complexity in children and, moreover, predict the optimal arousal level for children. Only few studies have dealt with measurement of perceived complexity in children (Leon et al., 1999; Reverdy et al., 2010).

By the use of Flash Profile, a sensory description of the six FMPs was achieved, and the large diversity between the samples was documented. It supported our statement that the six FMPs were designed to increase step by step in designed complexity as sample A, the least complex FMP, had the lowest intensity in almost all attributes, and sample F, the most complex FMP, had a very high intensity in all the attributes (Fig. 5). Furthermore, the Flash Profile was chosen to give a fast sensory description of each FMP compared to a more thorough and time-consuming description achieved from classical sensory profiling. The sensory attributes given by each assessor are acknowledged in the Flash Profile, implying that each assessor provides an individual configuration of the FMPs. Sensory attributes that would not reach agreement in a classical sensory profiling appear in the Flash Profile; i.e. one assessor evaluates that sample F tasted of marinated herrings and rotten fish, whereas another mentioned sour buttermilk as a sensory attribute for sample A. These special sensory attributes, mentioned by only a few assessors, could be very important for the food industry when developing new products, and they may explain some children’s rejection of the samples.

By the Flash Profile, it was possible to observe a large change in sensory quality from product C to D, indicating that addition of fibres had a significant effect of the sensory profile. Figure 5 shows that addition of fibres induced a higher degree of thickness, which triggered a drop in children’s
liking (Fig. 1 and 6). The decline in children´s liking was also observed according to sample E, in which large mango pieces were added. It can therefore be concluded that a change in texture seems to affect liking of FMP. As flavours were added to sample F, liking increased, which indicated that addition of flavours in the present concentration masked the presence of fibre and fruit. The positive effect of using flavours in masking techniques was also seen in a study by Luckow, Sheehan, Fitsgerald, & Delahunty, 2006. They found that tropical juice flavours were effective in masking the off flavours associated with probiotic ingredients, and that consumer liking for the probiotic juice was maintained over a 7-day exposure period. The combination of sensory data from the Flash Profile and data on children´s liking elucidates that steps where flavours were added (mango puree in sample C and pear and mango flavours in sample F) resulted in the highest liking compared to addition of stimuli that changed texture (samples B, D and E). It therefore seems that addition of flavours and the increase in complexity are drivers for children´s liking.

Hence, the results show that in Denmark it is possible to develop an FMP with fibres and a fruit content that is much higher than commercial FMPs without a loss in children´s liking. Actually, children had very high liking for the FMP with a high degree of designed complexity and a much healthier profile: lower sugar content, higher fibre and fruit content. Additionally, Figure 1 shows that it was possible to increase children´s liking for this healthy product in only 10 days!

5 Conclusion

The results from the present study show that 10 repeated exposures during 10 consecutive days to an FMP with a high level of designed complexity increased children´s optimal arousal level, resulting in an increased liking for more complex FMPs. The FMP with an arousal level near (and probably slightly higher than) the optimum seems to be more resistant to a decline in liking upon
repeated exposure than FMPs with a lower arousal level. The FMPs with the highest level of
designed complexity were the healthiest as they contained both fibres, large amounts of fruit and
were reduced in sugar content. This suggests that children´s liking for foods with a more healthy
profile can be increased by repeated exposure to foods with high complexity.
Additionally, Flash Profile appears to be a fast, convenient method to elucidate sensory attributes
important for liking. For FMPs, it can be concluded that addition of flavours is a driver for liking.
These results are important for basic studies of the effect of exposure on changing children´s liking
into a more healthy direction. Moreover, they are important in food innovation dealing with
children, health and obesity.
Reference List


Fig. 1. Mean rating scores for the six FMPs for all children pre-exposure. See Tables 1 and 2 for further details about samples A-F.

*Different lettering indicates statistically significant differences at $p<0.05$ for children’s liking between the six FMPs pre-exposure.
Fig. 2. Mean rating scores of six FMPs from the four experimental groups pre- (dark column) and post exposure (light column). See Tables 1 and 2 for further details about samples A-F.

Different lettering indicates statistically significant differences on $p<0.05$ in development of liking over the exposure period (14 days) with 10 exposures in the 3 exposure groups (Gr. 1 (n=49) exposed to sample A, Gr. 2 (n=53) exposed to sample D, Gr. 3 (n=49) exposed to sample F and the control group (n=47)) (see Table 3).
Fig 3. Position of the fermented milk products (FMPs) from the Multiple Factor Analysis (MFA) of the Flash Profile data (dimensions 1 and 2). See Tables 1 and 2 for further details about samples A-F.
Fig. 4. Position of the attributes that were most correlated to the first plan of the Multiple Factor Analysis (MFA). Each arrow corresponds to an attribute given by one assessor followed by the code of appearance (A), texture (TX) or taste (TA).
Fig. 5. Spider plot of eight attributes being highly relevant for the description of the variation between the six FMPs. See Tables 1 and 2 for further details about samples A-F.
Fig. 6. Relationship for FMPs varying in designed complexity between sensory attributes and children’s liking analysed by Principal Component Analysis (PCA Bi-plot). See Tables 1 and 2 for further details about samples A-F.
Table 1
Description of six FMPs varying stepwise in level of designed complexity

<table>
<thead>
<tr>
<th>Code</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>FMP</td>
</tr>
<tr>
<td>B</td>
<td>FMP + small pieces of pear</td>
</tr>
<tr>
<td>C</td>
<td>FMP + small pieces of pear + mango puree</td>
</tr>
<tr>
<td>D</td>
<td>FMP + small pieces of pear + mango puree + fibres</td>
</tr>
<tr>
<td>E</td>
<td>FMP + small pieces of pear + mango puree + fibres + large pieces of mango</td>
</tr>
<tr>
<td>F</td>
<td>FMP + small pieces of pear + mango puree + fibres + large pieces of mango + pear and mango flavour</td>
</tr>
</tbody>
</table>

The FMP used in sample A-F was a basic FMP added banana and pear puree.
<table>
<thead>
<tr>
<th>Ingredients</th>
<th>Conc.</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Banana puree</td>
<td>(g/l)</td>
<td>350</td>
<td>257</td>
<td>234</td>
<td>198</td>
<td>161</td>
<td>161</td>
</tr>
<tr>
<td>Pear puree</td>
<td>(g/l)</td>
<td>140</td>
<td>103</td>
<td>93.5</td>
<td>79.1</td>
<td>64.2</td>
<td>64.2</td>
</tr>
<tr>
<td>Sugar (g/l)</td>
<td></td>
<td>455</td>
<td>333</td>
<td>303</td>
<td>256</td>
<td>208</td>
<td>208</td>
</tr>
<tr>
<td>Modified starch E1442 (Trecomex AET 1)</td>
<td>(g/l)</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>9</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>(g/l)</td>
<td>43</td>
<td>12</td>
<td>13.5</td>
<td>19.4</td>
<td>12.3</td>
<td>10</td>
</tr>
<tr>
<td>Acidifying agent E330 (Citric acid)</td>
<td>(g/l)</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Na- benzoate</td>
<td>(g/kg)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Pear pieces (10*10 mm)</td>
<td>(g/l)</td>
<td>-</td>
<td>283</td>
<td>257</td>
<td>218</td>
<td>177</td>
<td>177</td>
</tr>
<tr>
<td>Mango puree</td>
<td>(g/l)</td>
<td>-</td>
<td>-</td>
<td>88</td>
<td>74.5</td>
<td>60.5</td>
<td>60.5</td>
</tr>
<tr>
<td>Fibres (Fibrulose F97 –Oligofructose 92%)</td>
<td>(g/l)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>144</td>
<td>118</td>
<td>118</td>
</tr>
<tr>
<td>Mango pieces (10*10 mm)</td>
<td>(g/l)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>189</td>
<td>189</td>
</tr>
<tr>
<td>Pear flavour (NN6254)</td>
<td>(g/l)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>Mango flavour (QL14321)</td>
<td>(g/l)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.75</td>
</tr>
<tr>
<td><strong>Dosage of marmalade to basic FMP</strong></td>
<td>%</td>
<td>11</td>
<td>15</td>
<td>16.5</td>
<td>19.5</td>
<td>24</td>
<td>24</td>
</tr>
<tr>
<td>Experimental group</td>
<td>n</td>
<td>Sample</td>
<td>Level of complexity</td>
<td>Gender (n)</td>
<td>Age</td>
<td></td>
<td></td>
</tr>
<tr>
<td>--------------------</td>
<td>----</td>
<td>--------</td>
<td>---------------------</td>
<td>------------------</td>
<td>-------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gr. 1</td>
<td>48</td>
<td>A</td>
<td>Low</td>
<td>29♂/19♀</td>
<td>12.7±1.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gr. 2</td>
<td>53</td>
<td>D</td>
<td>Medium</td>
<td>27♂/26♀</td>
<td>12.7±1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gr. 3</td>
<td>49</td>
<td>F</td>
<td>High</td>
<td>30♂/19♀</td>
<td>12.7±1.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>47</td>
<td>-</td>
<td>-</td>
<td>28♂/19♀</td>
<td>12.7±1.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

¹Mean age and std.dev. See Tables 1 and 2 for further details about samples A-F.