Research challenges and methods to study food preferences in school-aged children: A review of the last 15 years

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Abstract

Until only a few decades ago, there was little interest in research about children as consumers. Today, the food market for ‘‘the small consumers’’ is continuously growing and many foods and beverages are developed specifically for this target group. Furthermore, a better understanding of children's food preferences could also help design strategies to reduce obesity and malnutrition. The present review examines the main research domains in which measurement of children’s food preferences are applied and gives an overview of the progress made during the last 15 years in the field of consumer testing with children, highlighting the need of investigating and using new methods in addition to existing ones. Attention is also devoted to the choice of specific methods according to the child’s age.

An intense interest in consumer and sensory research with children is demonstrated by the systematic increase of scientific publications on this topic. A shift in research methodology has been observed in the last 15 years, being research more focused on feeding behavior and healthy eating. Recent investigations confirm that children in the age range of 4−11 years are able to perform most traditional consumer tests in addition to more sophisticated methods (e.g. projective mapping, memory and emotion evaluation) if age-appropriate procedures are adopted.

Keywords: consumer testing, food acceptability, male and female children, healthy eating, memory, emotion, wanting, observational studies

1. Introduction

Traditionally, there has been relatively little interest in children's food preferences. However, considering that food market for children is continuously growing, a wide variety of foods and beverages has been developed for this younger target group. In fact, children greatly influence purchases or even buy food themselves, and accordingly, the interest of food companies towards children in product development programs seems justified (Laureati, Pagliarini, Mojet, & Köster, 2011). Developing products for children requires their input since their wants and needs differ from those of adults. Differences in preferences or sensory acuity between children and adults, or both, are well established (de Graaf & Zandstra, 1999; Drewnowski, 1997; Liem, Mars, de Graaf, 2004; Zandstra & De Graaf, 1998). Literature data have reported marked age-related differences in sweet taste discrimination and preference (Liem et al., 2004) as well as in sour taste preference (Liem & Mennella, 2003). Likewise, texture preference has been found to vary from childhood to adulthood (Lukasewycz & Mennella, 2012; Zeindstra, Koele, Kok & de Graaf, 2010). Therefore, it is impossible to predict the nature of these differences without actual information from the intended target group. Furthermore, a better understanding of children's food preferences could also help design strategies to reduce obesity and malnutrition. Recently, international guidelines have been established on prevention and control of the so-called non-communicable diseases, with specific emphasis on childhood obesity (WHO, 2012). Several actions are proposed, one of which is aimed at shaping taste preferences from an early age through information and awareness campaigns addressed towards schools, families, and childhood aggregation centers. Food preferences, particularly in children (Birch, 1999; Laureati et al., 2015b), are indeed believed to play a central role in the prediction of human food choices (Drewnowski, 1997; Köster, 2009). In this context, sensory preferences and thus the methods used to explore them, play a key role for understanding the food behavior of children and directing them towards healthier food choices.

55 The sensory methods used with children have been reviewed by Guinard (2001) and Popper & Kroll
56 (2005). In these two review articles, the authors stressed the importance of using methods that are
57 appropriate for different age groups, considering the sensory, cognitive and social factors that may
58 impact testing with children. These issues are also included in the recently revised international
59 standard guideline on sensory evaluation by children and minors (ASTM, 2013).
60 Starting from these two articles, the present review firstly reconstructs the framework regarding the
61 study of children's preferences from 1980 to 2000. Next, the progress made from 2000 to 2015 in the
62 field of consumer testing (i.e. study of liking and preference) with children is examined with the aim
63 of identifying the main research domains and to show trends in application of consumer research with
64 children also in terms of new methods used, either together or in addition to existing ones. Specific
65 attention is also devoted to the appropriateness of methods according to children's age.
66

67 ## 2. Research domains for conducting sensory testing with children

68 A search for relevant papers and categorization of the research challenges of food sensory studies on
69 children is not an easy task since it is a highly multidisciplinary and heterogeneous area. Some
70 considerations may come from the number of cited papers in two relevant databases: Scopus (science,
71 technology, health, medicine, social sciences, arts and humanities) and Pubmed (more related with
72 health and medicine).
73 Considering the keywords "children food preferences" or "children food sensory" from 2000 to 2014,
74 without applying any filter, Scopus (http://www.scopus.com/) returned 3172 documents and Pubmed
75 (http://www.ncbi.nlm.nih.gov/pubmed) 1812; the increase over time is almost linear for both
76 databases with similar peaks in 2008 and 2012. The number of published papers increased
77 approximately 4.1-fold (Scopus) and 4.6-fold (Pubmed) from 2000 to 2014 **(Figure 1**). In 2013, there
78 was a decrease in the number of publications (ratio of publication 2013/2012=0.8), confirmed by the
79 same trend in 2014.

Looking at the subject areas present in databases, around one-third or one-fourth of the cited papers concern “Health and Medicine”, and it would appear that the sensory research on children has “Medicine” and “Nursing” as main subject areas (Scopus), followed by “Agricultural and Biological Sciences” even if many other areas have contributed to the increase in the number of publications during the period analyzed.

Articles were further categorized to identify specific research topics. To do so, after the initial search with the main keywords “children food preferences” or “children food sensory”, an additional search was made sorting papers by subject areas and keywords retrieved by databases. Following this approach, publications were grouped according to 7 main research areas as seen below:

1. Feeding behaviour (medicine, nutrition, psychology, education, sociology, food science)
2. Eating disorders (medicine, nutrition, psychology)
3. Healthy eating and nutrition education (medicine, nutrition, psychology and education)
4. Sensory perception (medicine, psychology, food science)
5. Consumer science (food science, economy)
6. Food quality (food science)
7. Food safety/prevention (food science, medicine)

A schematic overview of the 7 research areas and the links between them is depicted in Figure 2. In this conceptual map, the areas are represented as oval spots and their surface is reported roughly proportional to the number (of the total of about 3000 papers reported by Scopus) of manuscripts categorized by each; it should be considered that, due to the highly multidisciplinary topic, many articles are linked to or belong to more than one research area. The core and multidisciplinary challenge, in terms of the highest number of publications and cross relation with the other research areas, is the study of “feeding behaviour” (more than one-third of publications), which is radially connected by specific and characterizing groups of keywords with the other four main research areas, respectively, in a clockwise direction, from the top left of Figure 2: “eating disorders”, “healthy eating, nutrition education”, “consumer science” and “sensory perception”. On a second level, in

terms of the amount of related research, the challenge of the "food quality" is mainly, but not exclusively, linked with "sensory perception" and "consumer science"; "food quality" is related to a small and recent area in which sensory and preferences studies on children are associated with "food safety and prevention", e.g. risk perception of school food consumption (Kim, Kim, Park, Kang, Hwang, & Rhee, 2015). Starting from this framework, the present review focuses on the studies dealing with consumer science involving children. The following chapters examine the "healthier shift" taken from 1980 to 2015 in terms of research drivers and analyse the main methods used in consumer testing with children over the last 15 years.

3. Trends in consumer testing with children from 1980 to 2015: towards a healthier direction

The trend in the application of sensory and consumer testing with children from 1980 to 2015 is shown in Figure 3. Information about research challenges and methodologies from 1980 to 1999 is based on the analysis of the last two review articles by Guinard (2001) an Popper and Kroll (2005), whereas information about research conducted from 2000 till present is the result of a thorough analysis of the articles selected in the present paper.

In the last decades, a great deal of effort has been made to develop sensory methods that are suitable for children. More specifically, from 1980 to 1999 attention was essentially devoted to the discovery of methods that were appropriate for specific age groups and to apply such methods to find food formulations that met children's expectations. These techniques were mainly hedonic methods, although simple discriminant methods were also adopted.

Reviewing the literature on consumer testing with children during the last 15 years, a shift in research orientations can be clearly observed. In the 21th century, studies have mainly focused on healthy eating habits among young consumers. Sensory and hedonic methods are applied with the main purpose of food optimization to develop healthier options that are liked by children. To address this issue traditional methods are often found in the literature, although new approaches have been suggested and successfully applied with children. These new methods, which will be discussed in

132 section 4, consist mainly in projective mapping, sorting techniques and indirect approaches to explore
133 implicitly food preferences.
134 According to this shift in research orientation, and in agreement with research areas shown in the
135 conceptual map (Figure 2), most of the publications related to consumer testing with children in the
136 21th century have dealt with the topic of increasing acceptance and consumption of fruits and
137 vegetables (F&V) through food educational programs (Healthy eating, Nutrition and Education)
138 (Laureati, Bergamaschi & Pagliarini, 2014; Olsen, Ritz, Kraaij & Møller, 2012b; Reverdy, Schlich,
139 Köster, Ginon & Lange, 2010) or by using specific preparation methods (Poelman & Delahunty, 2011;
140 Poelman, Delahunty & de Graaf, 2013; Rohlfs Dominguez et al., 2013; Zeinstra et al., 2010). Other
141 studies have attempted to find the most age-appropriate procedure to investigate aspects (e.g. food
142 neophobia) related to low consumption of F&V (Laureati, Bergamaschi & Pagliarini, 2015a) or
143 investigate the relationship between children's food preferences, sensory sensitivity, and nutritional
144 status (e.g. BMI) (Feeney, O'Brien, Scannell, Markey & Gibney, 2014; Hartvig, Hausner, Wendin,
145 & Bredie, 2014; Hill, Wardle & Cooke, 2009; Laureati et al., 2015b; Suomela et al., 2012).
146 Several studies have also focused on product development or optimization of food formulations
147 destined for children (Food Quality, Consumer Science). These studies are linked with healthy choice
148 as well since they are mainly focused on finding new strategies for changing children's preferences
149 towards a more healthy direction. This is achieved by manipulating the fat content in food
150 formulations (Kildegaard, Løkke & Thybo, 2011a; Olsen, van Belle, Meyermann & Keller, 2011) or
151 by studying the sensory aspects that best correlate with children's acceptance of fruits (Kühn & Thybo,
152 2001; Thybo, Kühn & Martens, 2003; Torrieri, Di Monaco, Cavella & Masi, 2008), vegetables
153 (Brueckner, Schonhof, Schroedter & Kornelson, 2007), and whole-grain bakery products (Delk &
154 Vickers, 2007). In the context of food product development, several studies have focused on
155 optimization of school meals (Caporale, Policastro, Tuorila & Monteleone, 2009; Donadini, Fumi,
156 Vanoni & Porretta, 2012; Donadini, Fumi & Porretta, 2013; Hausner, Hartvig, Reinbach, Wendin &
157 Bredie, 2012; Lakkakula, Geaghan, Zanovec, Pierce & Tuuri, 2010; Pagliarini, Ratti, Balzaretti &

158 Dragoni, 2003; Pagliarini, Gabbiadini & Ratti, 2005), indicating a certain interest in consumer testing
159 with children in a real eating context. Other investigations have assessed specific sensory aspects (e.g.
160 taste and flavor) related to food perception (Sensory perception, Consumer Science, Food Quality)
161 (Lanfer et al., 2013; Liem & Mennella, 2003; Liem, Westerbeek, Wolterink, Kok, & de Graaf, 2004b;
162 Liem, Zandstra, & Thomas, 2010). Finally, a great deal of interest has been observed for gender-
163 related differences in food preferences during childhood in terms of comparison according to BMI
164 (Kimura, Endo, Minamimae, Kanzaki, & Hanaki, 2014) or efficacy of school-based interventions to
165 increase F&V preference (Cunningham-Sabo & Lohse, 2014).
166 The shift observed in the last 15 years in research orientation is a response to the increased rate of
167 overweight and obese children worldwide. This phenomenon may in part explain the increased
168 attention toward children's food preferences and the need of finding new alternative methods to
169 explore the hedonic dimension of young consumers. Traditional and new approaches used in
170 consumer testing with children during the last 15 years are reviewed in the following chapter.
171

172 **4. What's new in consumer testing with children? Overview of studies from 2000 to 2015**

173 A selection of studies published between 2000 and 2015 is reported in **Table 1**. We restricted the
174 search to the journals that typically publish articles presenting methodological advances in sensory
175 and consumer science or critically discuss sensory methodologies. These journals are Food Quality
176 and Preference (http://www.journals.elsevier.com/food-quality-and-preference/), Appetite, and
177 Journal of Sensory Studies. We used the keyword "children" within these journals in the period 2000-
178 2015, we checked the references list within the papers that were returned and then we manually
179 selected the articles based on the following criteria:
180 1) articles published in English language;
181 2) articles dealing with self-reported consumer testing (either a direct or an indirect measure of
182 liking/preference) with children (no parental report of the child's acceptability/preference);

3) articles involving at least 60 children, except if a smaller number was justified by the methodology (e.g. observational studies);

4) articles involving healthy children (e.g. no diabetes, autism, anorexia or bulimia);

5) articles which included children within the age range of 4 to 11 year.This specific age range has been chosen on the basis of the following criteria: 1) this is a critical period in children's life with respect to food preference development, since experience with food increases with age as does autonomy in food selection; 2) it is well established that starting from the age of 4 years, children can reliably perform most of the sensory tests such as discriminant and hedonic methods; 3) after the age of 11 years, a series of complex metabolic factors associated with puberty arise and influence body composition development (Loomba-Albretch and Styne, 2009).

Although the present review is mainly addressed on children aged between 4-11 years, a certain flexibility has been kept in the selection of papers, including, when necessary, articles that investigated a slightly broader age range (e.g. 9-14 or 3-5). This choice was made for those articles in which a deeper analysis according to children's age was performed, thus enabling investigation on the intended target group.

The literature search following these criteria returned 57 research articles (Table 1). We classified the articles in two categories according to the approach used to study food preferences: 1) direct methods corresponding to explicit approaches to measure preferences; these methods include traditional, well-known techniques (i.e. hedonic rating scales, ranking test, paired comparison test) as well as new approaches (i.e. projective mapping and sorting techniques); 2) indirect methods to implicitly evaluate food preferences; these methods correspond to new, alternative procedures devoted to the assessment of variables that are strongly related to food acceptance and that may provide important information for predicting or explaining liking (i.e. implicit paradigms to study the type of memory that children use for specific foods and ingredients; wanting evaluation; study of emotions in relation to choice of food).

4.1. Direct methods to study food preferences in children

4.1.1. Traditional approaches: paired comparison, ranking and rating scales

Table 1 provides an overview of the traditional and new methods applied from 2000 to 2015. Among the traditional methods, the most widely used were 5- and 7-point rating scales, accounting for more than 50% of all studies. The ranking test was frequently used as well, whereas other methods such as the paired-comparison test, 3-, 9-point and linear scales were used rarely. All these methods were applied independently of age, suggesting that children can reliably perform consumer testing if age-appropriate protocols are adopted. An in-depth description of the appropriateness of such traditional approaches according to children's age is reported in **Table 2**.

A comparison of different hedonic methods can be found in the studies by Kildegaard et al. (2011a) and Kildegaard, Tønning & Thybo (2011c). They investigated liking of different beverages in children aged 9−14 years using a 5-point hedonic facial scale and multiple ranking. Even if this age range exceeds that under investigation in the present review, the authors provided evidence that children in each age-group (including children aged 9-11 years) were able to discriminate products varying in sourness, fattiness, and fruit content according to liking. In addition, agreement between ranked and rated liking was observed, thus indicating the appropriateness of the two sensory methods. Similar findings were observed by Liem & Zandstra (2010) who found a high consistency between ranked and rated liking for different samples of margarine in 6−9 year-old children. Liem et al. (2004a) compared the ability of even younger children (4−5 years) with that of adults in discriminating the liking of an orange beverage varying in sweetness using ranking and paired-comparison tests. A high consistency between the two procedures was seen for 5-year-old children and adults. Four-year-old children performed poorly but were able to identify differences in preference across stimuli. Accordingly, Donadini et al. (2012) reported that children around 4−5 years were able to discriminate in terms of liking different types of cheese using a 5-point hedonic facial scale. This indicates that even young children can reliably perform hedonic tests. Cordelle, Piper & Schlich (2005) used both a linear unstructured scale and a paired-comparison test to investigate the consistency of liking

measurements in children aged between 9 and 12 years for beverages differing in taste or flavor. The use of unstructured scales with children is not common. However, in their study, Cordelle and colleagues added faces under the extreme anchors to help children to better understand the scale. A high coherence between the two liking measurements for all age groups was seen with no age-related differences in the use of the linear scale (same mean values and same dispersion across age groups). Poelman & Delahunty (2011) and Rollins, Loken, Birch (2010) used an approach in which the 3-point hedonic scale was combined with the ranking method. Both studies found good agreement between the two measurements. However, it should be underlined that this scale might not sensitive enough to represent the degree of liking by children (Lakkakula et al., 2010), especially older ones.

Evidence of the appropriateness of the 7-point hedonic facial scale use with children is reported by Laureati et al. (2011) and Laureati & Pagliarini (2013) who showed, respectively, that children are able to discriminate in terms of liking among different types of food and among different levels of sweetness of the same food. Similarly, the results of Pagliarini et al. (2005) revealed that 7-10-year-old children provide repeatable results when asked to assess liking for the same dish in two separate sessions. In their study, Pagliarini et al. (2005) found age-related differences in liking scores, with younger children providing systematically higher liking ratings than older ones. Similar age-related differences were reported by Moskowitz (2002) who showed that children aged 8 and 9 years had a slight bias to use the top of the 9-point liking scale compared to older peers. Pagliarini et al. (2005) speculated that the difference was not related to misunderstanding of the scale but rather to the development of preference due to the acquisition of a more critical attitude towards food as a consequence of exposure to a more varied diet rather than to different use of the scale. Interestingly, Caporale et al. (2009) reported that the 7-point hedonic facial scale may also be successfully administered to very young children (i.e. 4-5 years old) as they showed that hedonic ratings predicted subsequent food intake, thus demonstrating the predictive validity of the measurement.

In summary, recent studies on consumer testing with children confirm that they are able to perform all hedonic protocols, including the use of sophisticated hedonic scales. Given the reliability of

children, it seems advisable to opt for more discriminating tools such as a 5- or 7-point scale instead of a 3-point scale. Overall, care should be taken when establishing age-appropriate protocols, including child-friendly environments, simplified questionnaires (e.g. limited number of questions and pages), which should be read to younger children, tests in an individual setting or a small group, and use of warm-up samples to instruct children about the procedure should be carefully chosen and provided.

4.1.2. Traditional approaches: Computerized interactive visual preference

Improved skills in computers and increased use of the Internet have opened new possibilities to investigate visual consumer preferences. One example is the use of highly quality pictures to assess preference. This focuses on visual appearance, which is often the first sensation that arouses interest in a given food, especially for children (Moskowitz, 1994).

The use of non-tasting methods such as photographs of foods has previously been applied to younger children (Guthrie, Rapoport & Wardle, 2000), but interactive computerized measurement of children's preferences has received little attention. This procedure has been applied by Vereecken, Vandervorst, Nicklas, Covents and Maes (2010) to investigate F&V preferences among a sample of 4−6-year-old children showing a high reliability of the measurement, even if the relationship between the responses of children and parents was moderate. Olsen et al. (2012a) reported that the evaluation of images of foods in a computerized conjoint analysis provided reproducible information about visual food preferences in children 9−14 years, and the results were in concordance with both actual hedonic measures and product choices. No age-related differences in reproducibility were found, even though a tendency towards higher reproducibility with increased age was observed. Good correlation between visual preferences as expressed in the picture-based conjoint analysis and actual choice was also found by an earlier study of the same authors (Kildegaard, Olsen, Gabrielsen, Møller and Thybo, 2011).

Although the assessment of food preferences using real products is recommended, this approach can be of interest for interpreting purchase situations, where taste information is not available and consumers make decisions based on appearance Kildegaard et al. (2011b). In addition, it can be of help when rapid measurement of many products is needed or when a preliminary selection based on visual food properties is necessary for successive, more detailed evaluation. Another advantage that should be mentioned concerns simultaneous administration to multiple children, higher response rates, and fast and easy data processing, as well as suitability for online testing. It is thus an interesting approach in school-based educational programs. Some recommendations are reported for researchers who intend to apply such methodology: 1) the number of visual stimuli should be carefully considered, and take into account potential confusion and fatigue effects ; 2) it is a prerequisite that children are familiar with the foods they are looking at, so that their evaluations will indeed be based on liking rather than lack of familiarity; 3) it is possible to obtain information only for specific products attributes that are visually apparent.

4.1.3. New approaches: projective mapping and sorting techniques

The appropriateness of new approaches in consumer testing with children is reported in Table 3. Projective mapping and derived techniques are simple user-friendly procedures that have gained popularity within the field of sensory and consumer science. These methods have been applied with adults for several purposes, such as cross-cultural studies (Laureati, Pagliarini, Bassoli, & Borgonovo, 2014) or in comparison with descriptive methods (Holler Mielby, Hopfer, Jensen, Thybo, & Heymann, 2014). The technique allows consumers to express perceptual similarities/dissimilarities and grouping sets of products by placing them on a bidimensional surface. In its simplest form, it is a non-verbal method based on perceptual distances among products. Despite its simplicity, it has only recently been successfully tested on the young consumer. Varela & Salvador (2014) provided children aged 5, 7, and 9 years with pictures representing various healthy and unhealthy foods and asked them to allocate each picture on an A4 sheet separated in 4 equal quadrants labeled with 2 symbols each to

312 convey the 4 groups. The symbols used were a ‘‘yummy face’’ (a smiley figure with the tongue out),
313 a ‘‘yuck face’’ (smiley with a ‘‘do not like face’’), a devil (meaning ‘‘bad for you’’) and an angel
314 (meaning ‘‘good for you’’) to represent their liking and perception of healthiness. Next, children were
315 provided with the pictures and were asked to rate the liking of each item on a 7-point hedonic facial
316 scale. The results for the three age cohorts were very similar, and children were able to group products
317 taking into account both healthiness and hedonic perception as instructed.
318 Evidence of application of sorting techniques with school-aged children has been provided by Morizet,
319 Depezay, Combris, Picard, & Giboreau (2012) who reported that children are able to correctly classify
320 several vegetables according to liking and familiarity.
321 Although further research is needed to assess the potential of projective and sorting techniques for
322 assessing children’s preference - especially with more complex product sets and tasting real products
323 - it seems that the procedures can be easily understood. Moreover, the procedures are suitable to be
324 presented as a game in that can also be used with younger children. Therefore, projective mapping
325 and sorting tasks can be considered a promising tool in consumer research with children, but care
326 should be taken in explaining how to position the products so that children use the total space on the
327 map and use symbols to represent a few sensory concepts (hedonic valence or simple sensory
328 properties such as sweet, sour, bitter etc.).
329
330 *4.2. Indirect methods to study food preference in children*
331 To date, several measurements to assess children’s food liking and preference have been proposed.
332 One of the limit of“traditional” hedonic methods is that they reflect conscious cognitive processes,
333 whereas consumer acceptance is also based on unconscious processes, which may be measured by
334 implicit physiological and behavioural measures (Köster, 2003). In this section, the new approaches
335 proposed in addition to traditional hedonic measurements to interpret children’s food liking and
336 preference are reviewed, with particular reference to implicit paradigms used to investigate children’s
337 food memory, and methods to assess children’s wanting and emotions.

338

339 *4.2.1. Implicit paradigms to study food memory in children*

340 Over the last decade, a notable number of studies has been performed in an attempt to delineate the
341 mechanisms involved in incidental learning and memory of food. If we consider the way we learn,
342 store, and retrieve sensory food input, it is fairly evident that we rarely pay attention to what we eat
343 or drink, unless something differs from our expectations (Laureati & Pagliarini, 2013). Nevertheless,
344 sensory information is unconsciously retained by the brain and remains ‘‘hidden’’ until the time when
345 a new food is experienced (Köster, Prescott, & Köster, 2004). This aspect is particularly relevant for
346 food preference since at the critical moment of choice consumers seldom have the opportunity to taste
347 the product and base their choice on the expectation they have toward a particular product.
348 Consumer’s expectations, in turn, rely mainly on the information provided by memory. Although the
349 implicit nature of food memory is evident, most of the available studies on memory of sensory stimuli
350 deal with conscious and intentional mechanisms of learning. As regarding children, studies are
351 focused on explicit paradigms to investigate the relationship between flavor labeling and recognition
352 of flavor in children (Frank, Brearton, Rybalsky, Cessna & Howe, 2011; Lumeng, Zuckerman,
353 Cardinal & Kaciroti, 2005). However, this approach is reductive as it does not take into consideration
354 the incidental component of memory processes and the understanding of food memory under normal
355 conditions. This limitation has been underlined by Jos Mojet and Ep Köster who tried to overcome
356 the lack of ecological validity in food memory research by validating an incidental learning paradigm
357 to study food memory in a natural setting (Mojet & Köster, 2002). Through the application of this
358 paradigm with adults, some food memory features have been delineated (see Morin-Audebrand et al.,
359 2012 for review).
360 Very recently, this paradigm has been also tested successfully with children. For instance, Laureati,
361 Morin-Audebrand, Pagliarini, Sulmont-Rossé, Köster, & Mojet (2008) compared incidental learning
362 and memory for a custard dessert in three sensory modalities (i.e. taste, flavor, and texture) involving
363 children (9−11 years old) and adults (18−45 years old). They found that children had good recall of

364 the custard dessert eaten the day before (i.e. target) in terms of liking, whereas the distractors with
365 increased concentration of sugar and cherry aroma were remembered as less pleasant than the target.
366 Moreover, no age-related differences in the way food is remembered were found, underlining that
367 children understood the task and were able to precisely store and retrieve information about the food
368 they eat. Accordingly, Laureati, Pagliarini, Mojet, & Köster (2011) investigated incidental learning
369 and memory for three different food stimuli that varied in sweet taste in children between 7–10 years.
370 They reported that children clearly recognized the distractors at different levels of sweetness as being
371 different from the memory of the target product eaten the previous day, but memory was product-
372 dependent, a result already observed in adults (Köster et al., 2004; Morin-Audebrand, Laureati,
373 Sulmont-Rossé, Issanchou, Köster, & Mojet, 2009). In general, these studies showed better memory
374 performance in a relative memory task (i.e. remembering a specific characteristic, such as liking, of
375 the target and distractors) compared with an absolute memory task (i.e. recognizing the target among
376 a series of distractors). The prominence of memory for liking, over absolute memory, has interesting
377 practical implications. In fact, when making a choice, consumers usually choose on the basis of their
378 previous experience with a product, i.e. their memory for the liking or disliking of a product. If these
379 memories deviate from the actual experiences, the representation in memory may be the most
380 important predictor in food choice.
381 Clear evidence of children's reliability in performing memory tasks was also provided by Laureati &
382 Pagliarini (2013) who showed that children were able to recognize distractors varying in different
383 levels of sweetness from memory, hedonic (7-point facial hedonic scale), and perceptive (paired
384 comparison) points of view. Interestingly, they also found that children's memory was better under
385 incidental rather than intentional conditions. This outcome has the important methodological
386 implication, that explicit paradigms should be cautiously considered when applied for studying food
387 learning and memory. This is because they are probably not appropriate, and are less ecologically
388 valid than implicit experimental procedures.

In summary, even if no general conclusions can be drawn from food memory studies due to the small numbers of papers and the limited number of children assessed, it seems recommendable to include memory tests among the criteria for industrial market launch decisions, since food expectations and food liking depend to a large extent on incidentally learned memory. In this context, the evaluation of relative memory in children for liking seems to be especially appropriate since it can provide new information that is not normally captured by measuring liking. First, it can highlight memory shifts, which as an indicator of unmatched expectations plays a crucial role in food choice; second, it can be more discriminative that the traditional measurement of liking (Laureati et al., 2008, 2011). Moreover, food developers should keep in mind that young consumers can perceive even the smallest sensory differences of a given food product and, more importantly, are able to learn and involuntarily memorize such variations.

4.2.2. Wanting evaluation

Research indicates that not only liking but also wanting plays an interdependent role in food choice and consumption in adults, which highlights the importance of the 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, while liking is not sufficient to predict wanting (Mela, 2001). Studies focusing on children's liking and wanting as separate pathways for food choice are limited but interesting, as there is evidence that the decrease in wanting, rather than liking, may explain boredom effects due to repeated exposure to food stimuli (Liem & Zandstra, 2009). Since repeated exposure is often used in sensory research with children to increase acceptance of healthy food, studying wanting in children might provide further information to better explain their food behavior. In this context, Liem & Zandstra (2009) investigated the influence of repeated consumption of snack foods on children's liking and wanting. Interestingly, the results revealed that wanting rather than liking was most affected by repeated daily consumption over a period of 3 weeks, but the effect of liking on the

prediction of food choice was consistently larger than the effect of wanting. Kildegaard et al. (2011a,c) also investigated liking and wanting in children as separate pathways. In these studies, no difference between liking and wanting was observed, but rather the two measures were highly correlated and children segmentation according to appreciation for sour food was very similar to that obtained through wanting data (Kildegaard et al., 2011c). Other studies carried out with children measured their desire to eat a variety of healthy and unhealthy foods but without taking in consideration the relationship with liking (Jansen, Mulkens, & Jansen, 2007; Jansen, Mulkens, Emond & Jansen, 2008). Although these studies indicate that children seem to be able to answer questions related to the desire to eat, some limitations should be highlighted. First, the hedonic scales used for rating liking and wanting were very similar. Both measurements consisted of a 5-point facial scale in which the extremes where represented by the same icons, i.e. the same sad face was used to represent the minimum degree of both liking and wanting scale, and the same smiley face was used to anchor the maximum degree of both liking and wanting. Second, wanting and liking evaluations were conducted in the same session or with only a short time interval between the assessment of liking and wanting. This could bias the results and lead to underestimation of the difference between liking and wanting. Research with adults suggests that introspective ratings are vulnerable to cross-contamination, meaning that distinct sets of underlying processes (liking *vs.* wanting) may be interpreted as a single variable (Berridge, 1996). This can be of particular relevance when children are involved, since they can have even more difficulties than adults in discriminating the concept of desire to eat from that of liking. One way to overcome this limitation is by using clearly distinct scales for liking and wanting evaluation (e.g. wanting might be represented through images of the size of product the child wants to eat) and, if possible, conduct the two measurements in separate sessions or with an appropriate time interval between them. Another option could be to consider the adoption of an implicit approach (e.g. behavioral tasks, physiological correlates, etc.) to measure food wanting, which has been shown to work well with adults (Finlayson, King, & Blundell, 2008). The approach has the advantage of using simple behavioral tasks (e.g. choosing the food a person mostly wants to eat in a forced choice

441 methodology) to obtain an indirect measure of wanting such as reaction time, which can be easily
442 adapted to methodologies used with children.
443
444 *4.2.3. Emotion evaluation*
445 *4.2.3.1. Use of questionnaires*
446 Research on adults has found that the measurement of emotions can be used to explore differences
447 between food products when the acceptability or preferences for the products are similar (King &
448 Meiselman, 2010; Jaeger, Cardello, & Schutz, 2013). Certain foods are more attractive and successful
449 on the market than others simply because they make us feel good; in other words, they trigger positive
450 emotions. The study of emotions in relation to food choice has recently been investigated by King &
451 Meiselman (2010) and De Smet & Schiffertein (2008). In these studies, feelings during food
452 consumption were measured using verbal standardised questionnaires, which could be too difficult
453 and not suitable to use as they are with children. Gutjar et al. (2014) noted that implementing emotion
454 measurement with a consumer defined and product and language specific emotional lexicon improves
455 discriminative sensitivity, such as in the Check All That Apply (CATA) approach of Ng, Chaya &
456 Hort (2013) and in the EmoSemio approach of Spinelli, Masi, Dinnella, Zoboli, & Monteleone (2014).
457 Consequently, it could be suggested that this approach, which is more language sensitive can be
458 suitable for use with children.
459 De Pelsmaeker, Schouteten, & Gellynck (2013) recently investigated whether 8−13-year-old children
460 associate different emotions with different brands of flavoured milk. In this study, the children
461 themselves generated a list of 20 emotions taken from previous research by Desmet & Schifferstein
462 (2008) and King & Meiselman (2010) that subsequently classified as positive, negative, or neutral.
463 Children were helped in understanding the meaning of the emotions and were free to add their own
464 terms, e.g. childish. The CATA method was then used to link these 20 emotions to six brands of
465 flavoured milk. It was seen that all emotions except one discriminated the six brands of milk. More
466 specifically, children associated more positive emotions with the leader brands and more negative

emotions with less known products such as rice and soy milk, thus suggesting they understood the task. Unfortunately, emotions were not compared with any liking measurement of the products, and thus it is not possible to conclude whether the emotion profile is more discriminating than liking for acceptability evaluation of flavoured milk. However, this first study on children's emotion related to food has the merit of having conducted the experiment in a real and trusted environment (i.e. at school), without the presence of parents which can be seen as a barrier for children to express their own opinions. Moreover, the report did not provide evidence of differences in performance according to age, and thus further research is needed to address this issue.

4.2.3.2. Observational studies

Emotions and cognitive associations with foods may also be measured with the help of advanced non-verbal and/or non-invasive physiological measures. As these measures do not rely on cognitive development, they may be more suitable for children. Non-verbal measures include facial expressions, which signal emotion of the face. In this context, facial expression evaluation can be seen as a useful tool to investigate aspects related to the hedonism of food consumption that cannot be investigated by applying traditional methods. Observational techniques provide objective measures, with orofacial actions (e.g. lip licking, tongue protrusion) to food cues used as markers of implicit affective processing in animals and humans (Schaal, Marlier, & Soussignan, 2000; Steiner, Glaser, Hawilo, & Berridge, 2001). In addition, this approach is independent of the cognitive skills of children, thus overcoming some difficulties that might be encountered in sensory testing with children due to their short attention span and reduced cognitive or language ability. Well-known examples in the food domain include the findings of Steiner's and colleagues (Steiner, 1973; Steiner et al., 2001) which revealed that infants can recognize and discriminate between various basic tastes and odors. More specifically, newborn infants show differentiated facial responses to various basic solutions: a sweet taste elicits facial relaxation, sucking, tongue protrusions, and may lead to a smile; a sour taste elicits

lip pursing; a bitter taste gives rise to head turns, mouth gaping, nose wrinkling and lowered mouth corners; and a salty taste has a less distinctive pattern.

Observational studies have gained increasing attention in the last decade in response to the availability of specific software (e.g. Face Reader) that can translate facial muscle movements into basic expressions (e.g. happy, sad, angry, surprised, scared, disgusted, and neutral) based on the Facial Action Coding System developed by Ekman (Ekman, 1992).

Examples of its application in observational studies in school-age children are less frequent in the literature than those in infants, but they have produced promising results that help to better understand and interpret the development of food preferences in children. In a recent study by Soussignan, Schaal, Boulanger, Gaillet, & Jiang (2012), distinct measures of liking (oro-facial reactivity, liking, wanting, and preference) for visual and odor cues related to food and non-food items were compared in 6−11-year-old children. It was found that orofacial reactivity to food cues is a valid measure of positive appetitive responses, and in particular lip sucking was clearly associated with higher liking for both visual and olfactory food cues. In addition, orofacial reactivity discriminated overweight children from normal-weight children, with the former displaying a higher frequency of lip sucking when exposed to high-energy dense food pictures and food odorants. This differentiation was not obtained through self-rated liking, wanting, or preference, thus suggesting that facial expressions might be more sensitive than self-reports for predicting a potential risk for the development of overweight/obesity.

In contrast, Zeinstra, Koelen, Colindres, Kok, & de Graaf (2009) found that facial expressions are suitable to measure dislike, but not to measure various gradients of food acceptance in children aged 5–13 years. Negative facial expressions for disliked food stimuli were easily recognized, whereas the distinction between a positive or neutral expression was less clear. This outcome is understandable, since the foods that humans consume and accept may result in mild positive reactions, thus making it more difficult to distinguish gradations of food acceptance based on facial expressions. Similar findings were reported by de Wijk, Kooijman, Verhoeven, Holthuysen, & de Graaf (2012) who

compared facial expressions in response to the sight, smell, or taste of liked and disliked food in children (8−10 years old) and adults and concluded that facial expressions successfully reflect negative but not positive food preferences. Of course, these results should be interpreted with caution as the number of children involved was rather low (from 6 to 40).

Observational studies have undoubted strengths that must be highlighted, such as the previously mentioned ability to capture implicit reactions that cannot be extrapolated using traditional methods and the reduction of burden and fatigue seen in some traditional hedonic tests requiring multiple sample tasting (e.g. complete rank order) as only one tasting is sufficient to register a reaction. However, when the approach is applied to school-aged children, the environment in which the observation is conducted should be considered with caution as a laboratory context may influence expressiveness. In this context, control of facial expressions and the ability to intentionally make faces develops gradually in the growing child. Although 5- and 12-year-old children appear equally capable in masking their facial expressions in response to unpleasant odors (Soussignan & Schaal, 1996), it is unclear how much masking and control occurs in response to food stimuli. Finally, facial recognition systems for emotions depend on small lists of emotions, thus missing potentially valuable information. Longer and more tailored lists of emotions are indeed recommended when working with a new product category in order to fully present the emotional response of consumers (King & Meiselman, 2010). All these issues should be considered as challenges in future observational research with children.

5. Conclusions

Review of the scientific literature on consumer testing with children in the last 15 years brings about the following main considerations. First of all, the intense interest in this research area is demonstrated by the systematic increase of scientific publications on sensory research in children. However, a shift in research methodology has been observed. While from 1980 to 2000 most studies were aimed at devising appropriate procedures to use in food product development with children, the major focus

544 of the most recent studies is to use sensory research to study feeding behavior and to promote healthy
545 eating among children.
546 Recent investigations confirm that children in the age range of 4−11 years are able to perform most
547 traditional consumer tests in addition to more sophisticated methods (e.g. memory and emotion
548 evaluation) if age-appropriate procedures are adopted. Using indirect methods to study variables that
549 are closely related to liking seems promising to better understand food behavior in children, and we
550 encourage their application when traditional methods cannot provide much information. Some of the
551 recent procedures still require optimization and validation. This is especially true in observational
552 studies, which are undoubtedly effective in very young children, but which have limitations in school-
553 age children and pre-teens. Additionally, questionnaires on emotions should be validated in terms of
554 reliability and predictive validity (e.g. measurement of liking paired to emotion evaluation is
555 encouraged). Finally, when applying consumer testing with children, care should be taken in
556 establishing age-appropriate protocols, including child-friendly environments, to perform the test. In
557 particular, simplified questionnaires (e.g. limited number of questions and pages), which should be
558 read to younger children, tests in an individual setting or a small group, taking into consideration the
559 sex/gender variable, and use of warm-up samples to instruct children about the procedure, should be
560 carefully chosen and provided.

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791 *Table 1. Summary of the most relevant studies published between 2000 and 2015.*

Article	Age range (y)	New hedonic methods	Traditional hedonic methods							
			paired-test	ranking	3-point	5-point	7-point	9-point	Linear scale	Other
1. Brueckner et al. 2007	7-11								x	
2. Caporale et al. (2009)	4-5						x			
3. Cordelle et al. (2005)	7-12; 18-60		x						x	
4. De Pelsmaeker et al. (2013)	8-13	Emotion								
5. de Wijk et al. (2012)	8-10; 22	Facial expression								
6. Delk &Vickers (2007)	8-12					x				
7. Donadini et al. (2012)	4.5-5.5					x				
8. Donadini et al. (2013)	5					x				
9. Feenay et al. (2014)	7-13					x				
10.Hartvig et al. (2014)	9-11						x			
11.Frank et al. (2011)	4-11	Food memory								
12.Hartvig et al. (2015)	9-11						x			
13.Hausner et al. (2012)	9-11						x			
14.Hill et al. (2009)	7-9					x				
15.Jansen et al. (2007)	5-6	Wanting								
16.Jansen et al. (2008)	5-7	Wanting								
17.Jiang et al. (2013)	6-11	Wanting					x			
18.Kildegaard et al. (2011a)	9-14	Wanting		x		x				
19.Kildegaard et al. (2011b)	9-13			x						
20.Kildegaard et al. (2011c)	9-14	Wanting		x		x				
21.Kühn & Thybo (2001)	9-13					x				
22.Lakkakula et al. (2010)	9-11				x					
23.Lanfer et al. (2013)	6-9		x							
24.Laureati et al. (2008)	8-10	Food memory					x			
25.Laureati et al. (2011)	8-10	Food memory					x			
26.Laureati et al. (2013)	8-10	Food memory					x			
27.Laureati et al. (2014)	6-10						x			
28.Laureati et al. (2015a)	6-10						x			

29.Laureati et al. (2015b)	6-10						x				
30.Liem & Mennella (2003)	5-9; 37-39			x							
31.Liem & Zandstra (2010)	6-9			x		x					
32.Liem et al. (2004a)	4-5; 20.8-24.4		x	x							
33.Liem et al. (2004b)	7-12			x							
34.Liem & Zandstra (2009)	7-12	Wanting		x		x					
35.Liem et al. (2010)	3-10			x							
36.Lumeng et al. (2005)	3-6	Food memory									
37.Morizet et al. (2012)		Sorting									
38.Moskovitz (2002)	8-14							x			
39.Olsen et al. (2011)	4-6					x					
40.Olsen et al. (2012a)	9-11; 13-15			x		x					
41.Olsen et al. (2012b)	9-11						x				
42.Pagliarini et al. (2003)	7-8						x				
43.Pagliarini et al. (2005)	7-10						x				
44.Poelman & Delahunty (2011)	5-6				x						
45.Poelman et al. (2013)	5-6					x					
46.Reverdy et al. (2010)	8-11						x				
47.Rohlfs Dominguez et al.(2013)	4-6				x						
48.Rollins et al. (2010)	5-11			x	x						
49.Soussignan et al. (2012)	6-11	Facial expression/wanting					x				
50.Suomela et al. (2012)	5-10							x			
51.Thybo et al. (2003)	6-10					x					
52.Torrieri et al. (2008)	6-14					x					
53.Varela & Salvador (2014)	5; 7; 9	Projective mapping					x				
54.Vereecken et al. (2010)	4-6				x						
55.Vigneau et al. (2012)	5-10										score and rank
56.Zeinstra et al. (2009)	5-13	Facial expression									
57.Zeinstra et al. (2010)	4-8; 11-12; 18-25			x							
		Tot (n)	3	12	5	15	17	2	2	1	5
		Tot (%)	5.3	21.0	8.8	26.3	29.8	3.5	3.5	1.8	1

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793 *Table 2. Appropriateness of traditional hedonic methods used with children aged 4 to 11 years.*
794 *Summary of the most relevant findings of studies carried out in 2000-2015.*
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Traditional methods	**Age range (years)**			
	4−5	**6−7**	**8−9**	**10−11**
Paired comparison	Yes [1]	–	Yes [2]	Yes [2]
Ranking	Yes [1, 3-5]	Yes [3-6]	Yes [3-4, 6-8]	Yes [4, 7-8]
Hedonic scales:				
3-point	Yes [4-5]	Yes [4-5]	Yes [4]	Yes [4]
5-point	Yes [6, 9]	Yes [6]	Yes [6-8]	Yes [7-8]
7-point	Yes [10]	Yes [11-13]	Yes [11-13]	Yes [11-13]
9-point	–	–	Yes [14]	Yes [14]
Unstructured linear	–	–	Yes [2]	Yes [2]

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797 (1) Liem et al. (2004a); (2) Cordelle et al. (2005); (3) Liem & Mennella (2003); (4) Rollins et al.
798 (2010); (5) Poelman & Delahunty (2011); (6) Liem & Zandstra (2010); (7) Kildegaard et al. (2011a);
799 (8) Kildegaard et al. (2011c); (9) Donadini et al. (2012); (10) Caporale et al. (2009); (11) Pagliarini
800 et al. (2005); (12) Laureati et al. (2011); (13) Laureati & Pagliarini; (14) Moskowitz (2002)
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Table 3. Appropriateness of new hedonic methods used with children aged 4 to 11 years. Summary of the most relevant findings of studies carried out in 2000-2015.

New methods	**Age range (years)**			
	4−5	**6−7**	**8−9**	**10−11**
Projective mapping and sorting	Yes [1]	Yes [1]	Yes [1, 17]	Yes [1, 17]
Implicit/Explicit memory	Yes [2, 3, 6]	Yes [2, 3, 5]	Yes [2, 4-6]	Yes [2, 4-6]
Wanting	Yes [7-8]	Yes [7-11]	Yes [9-13]	Yes [9-13]
Emotion (questionnaires)	–	–	Yes [14]	Yes [14]
Emotion (observational studies)	No [15]	No [15], Yes [10]	No [15-16], Yes [10]	No [15-16], Yes [10]

(1) Varela & Salvador, 2014; (2) Frank et al., 2011; (3) Lumeng et al., 2005; (4) Laureati et al., 2008; (5) Laureati et al., 2011; (6) Laureati et al., 2013; (7) Jansen et al., 2007; (8) Jansen et al., 2008; (9) Jiang et al., 2013; (10) Soussignan et al., 2012; (11) Liem & Zandstra (2009); (12) Kildegaard et al., 2011a; (13) Kildegaard et al., 2011c; (14) De Pelsmaeker et al., 2013; (15) Zeinstra et al., 2009; (16) de Wijk et al., 2012; (17) Morizet et al. (2012).

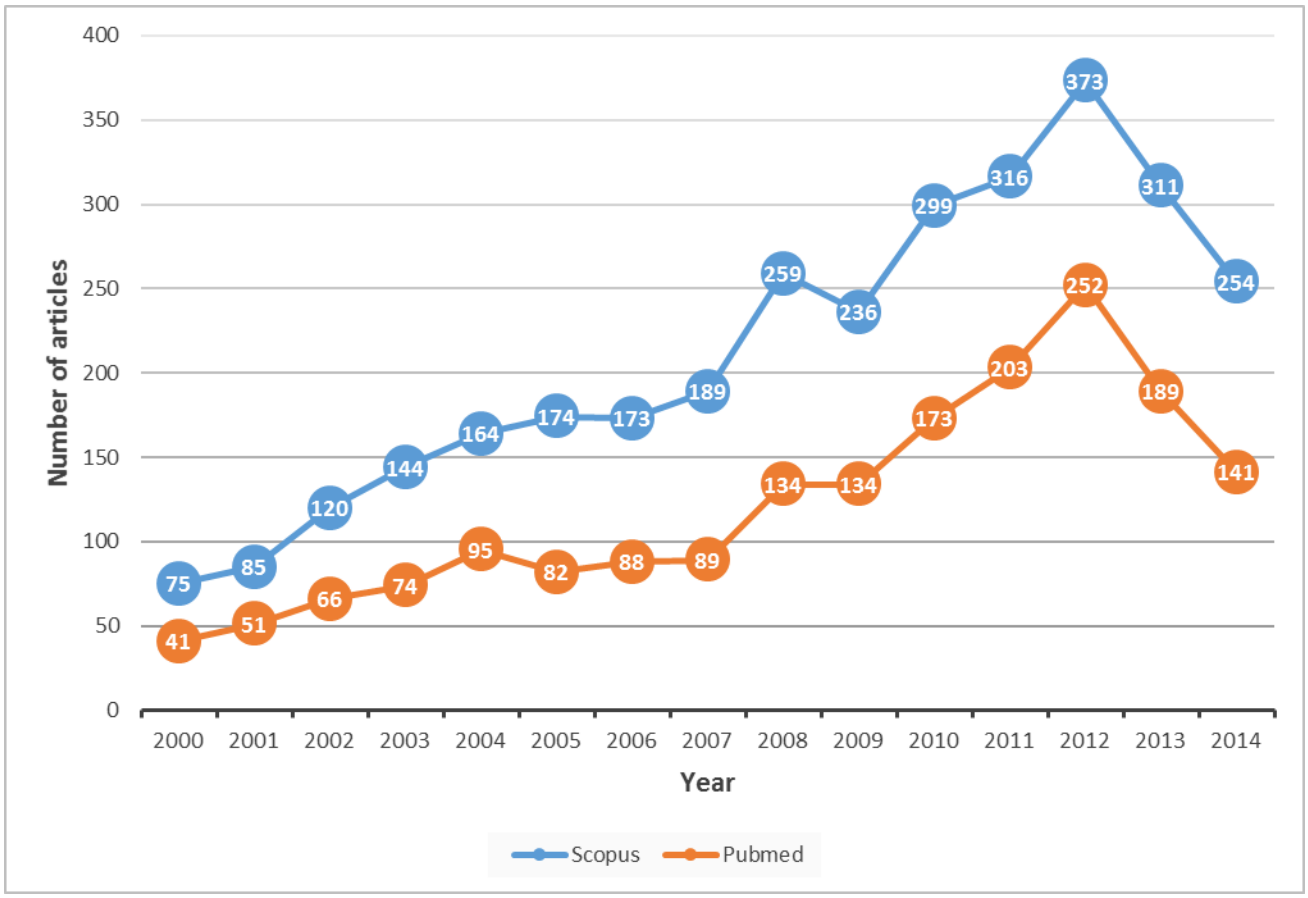

Fig. 1. Number of paper cited by Scopus and PubMed in 2000−2014, sorted by the keywords "children food preferences" or "children food sensory".

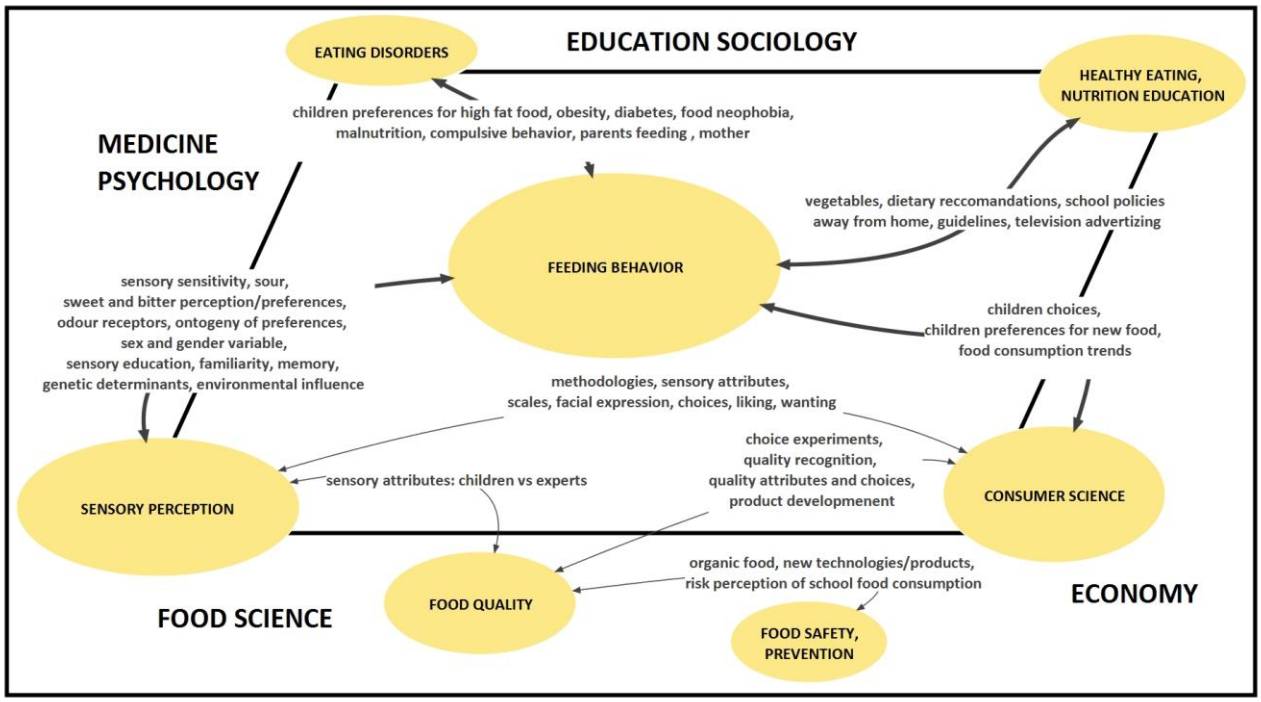

Fig. 2. Conceptual map of the main areas for measuring the sensory aspects and the food preferences of children. Groups of keywords were used to "tag" the interconnections.

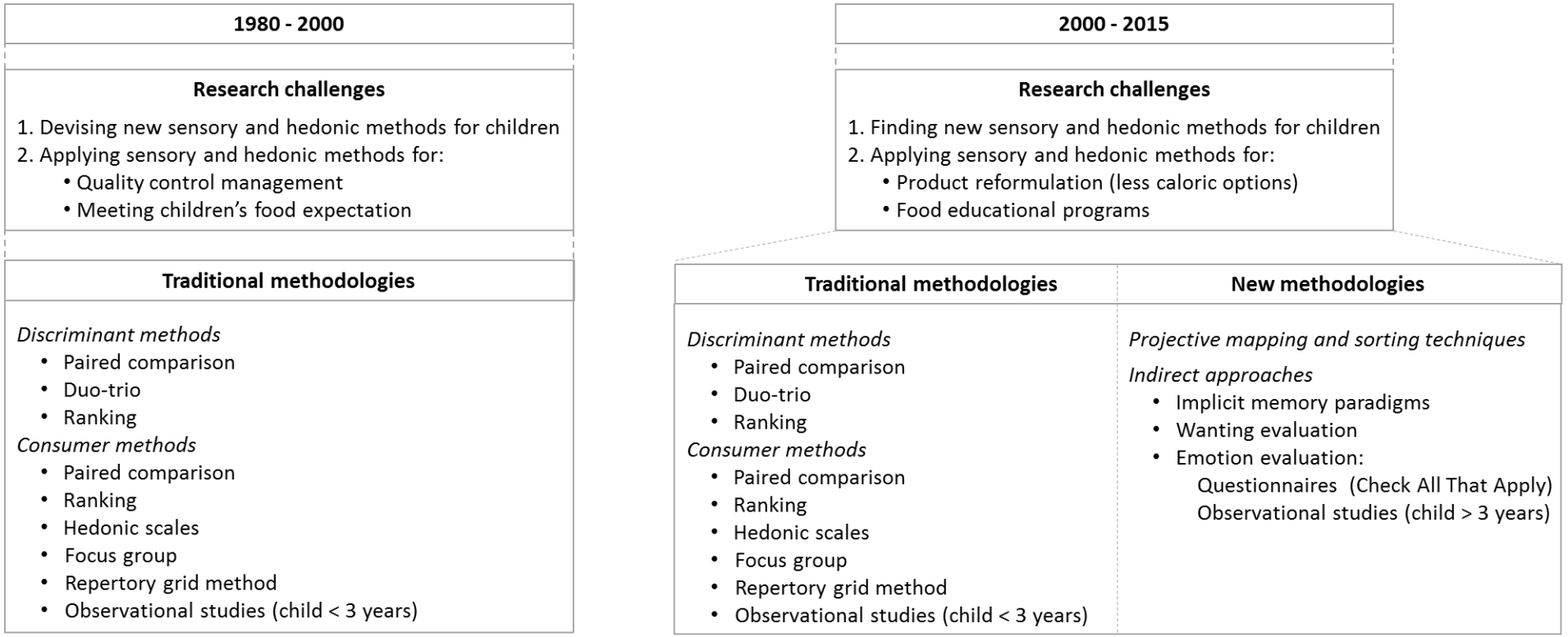

Figure 3. Overview of the trend in the application of sensory and consumer testing with children from 1980 to 2015