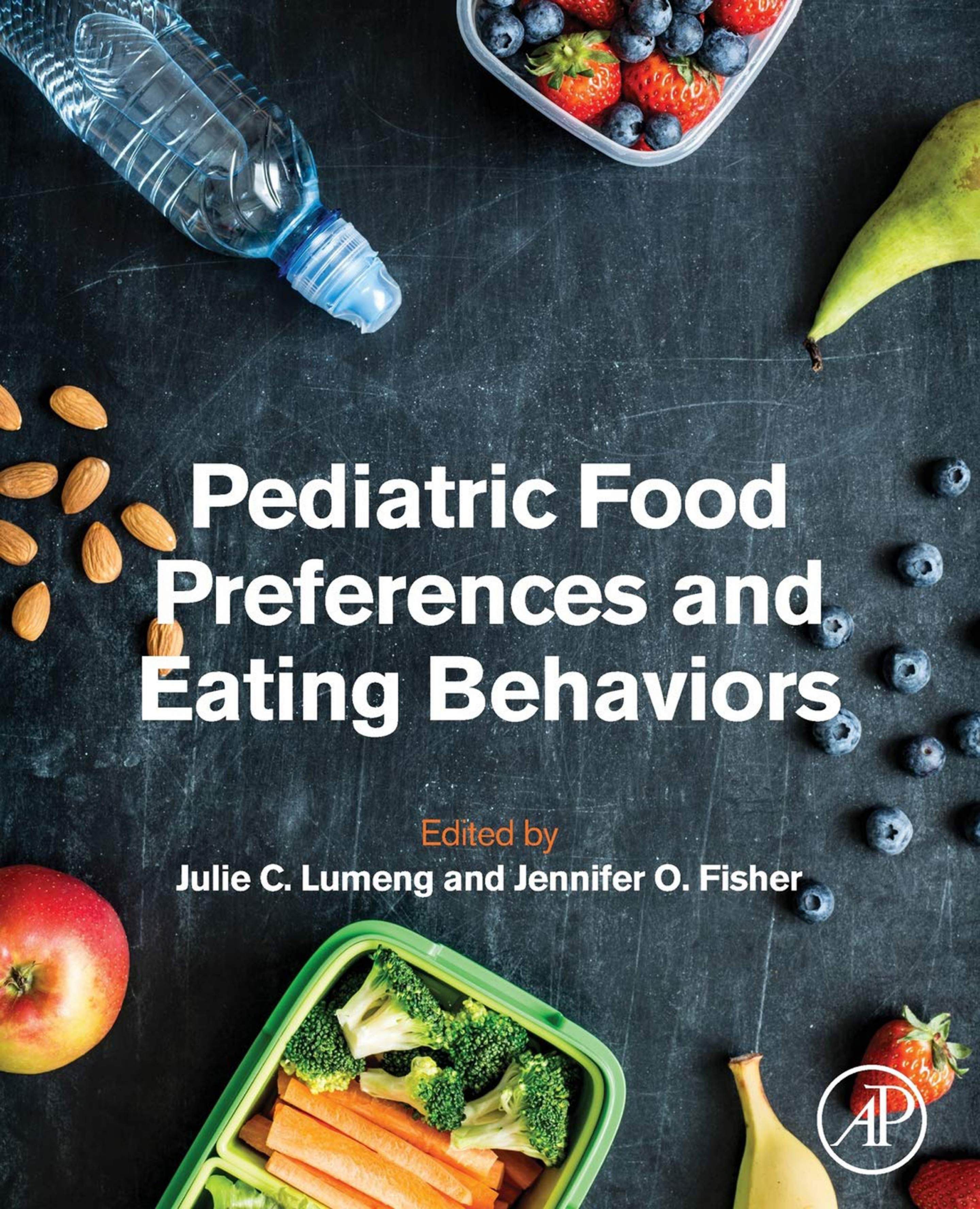

Pediatric Food Preferences and Eating Behaviors

Edited by

Julie C. Lumeng and Jennifer O. Fisher

PEDIATRIC FOOD PREFERENCES AND EATING BEHAVIORS

PEDIATRIC FOOD PREFERENCES AND EATING BEHAVIORS

Edited by

JULIE C. LUMENG
Department of Pediatrics, Medical School, and Department of Nutritional Sciences, School of Public Health, University of Michigan

JENNIFER O. FISHER
Center for Obesity Research and Education, Department of Social and Behavioral Sciences, Temple University, Philadelphia, PA

ELSEVIER

ACADEMIC PRESS
An imprint of Elsevier

Academic Press is an imprint of Elsevier
125 London Wall, London EC2Y 5AS, United Kingdom
525 B Street, Suite 1650, San Diego, CA 92101, United States
50 Hampshire Street, 5th Floor, Cambridge, MA 02139, United States
The Boulevard, Langford Lane, Kidlington, Oxford OX5 1GB, United Kingdom

Notices

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

British Library Cataloguing-in-Publication Data
A catalogue record for this book is available from the British Library

ISBN 978-0-12-811716-3

For information on all Academic Press publications
visit our website at https://www.elsevier.com/books-and-journals

Publisher: Andre Gerhard Wolff
Acquisition Editor: Megan R. Ball
Editorial Project Manager: Amy M. Clark
Production Project Manager: Prem Kumar Kaliamoorthi
Cover Designer: Greg Harris

Typeset by SPi Global, India

DEDICATION

To Carey, Avery, Payton, and Kieran for their love, support, and patience.

—Julie C. Lumeng

To LLB whose scientific curiosities and work inspired this field of study; to MWO, TRO, and IRO for their unconditional love and support, and for providing a stimulating living laboratory around the table; and to my parents for raising me with a love of learning and my mom's homemade food.

—Jennifer O. Fisher

CONTRIBUTORS

Stephanie Anzman-Frasca
Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, United States

Katherine W. Bauer
Department of Nutritional Sciences, University of Michigan School of Public Health, Ann Arbor, MI, United States

Laura L. Bellows
Department of Food Science and Human Nutrition, Colorado State University, Fort Collins, CO, United States

Leann L. Birch
Department of Foods and Nutrition, The University of Georgia, Athens, GA, United States

Jacqueline Blissett
Department of Psychology, School of Life and Health Sciences, Aston University, Birmingham, United Kingdom

Nuala Bobowski
Monell Chemical Senses Center, Philadelphia, PA; St. Catherine University, St. Paul, MN, United States

Amanda S. Bruce
Department of Pediatrics, University of Kansas Medical Center, Kansas City, KS; Center for Children's Healthy Lifestyles and Nutrition, Children's Mercy Hospital, Kansas City, MO, United States

Brenda Burgess
Department of Family Medicine, Jacobs School of Medicine and Biomedical Sciences, University at Buffalo—SUNY, Buffalo, NY, United States

Meghan Byrne
Department of Medical and Clinical Psychology, Uniformed Services University of the Health Sciences, Bethesda, MD, United States

Sam Chuisano
Department of Nutritional Sciences, University of Michigan School of Public Health, Ann Arbor, MI, United States

Jasmine M. DeJesus
Department of Psychology, University of North Carolina at Greensboro, Greensboro, NC, United States

Sarah Ehrenberg
Jacobs School of Medicine and Biomedical Sciences, University at Buffalo, Buffalo, NY, United States

Myles S. Faith
Department of Counseling, School and Educational Psychology, Graduate School of Education, University at Buffalo—SUNY, Buffalo, NY, United States

Lori A. Francis
Department of Biobehavioral Health, College of Health and Human Development, The Pennsylvania State University, University Park, PA, United States

Ashley N. Gearhardt
Department of Psychology, University of Michigan, Ann Arbor, MI, United States

Sheryl O. Hughes
Department of Pediatrics, USDA/ARS Children's Nutrition Research Center, Baylor College of Medicine, Houston, TX, United States

Susan L. Johnson
Department of Pediatrics/Section of Nutrition, University of Colorado Anschutz Medical Campus, Aurora, CO, United States

Kathleen L. Keller
Department of Nutritional Sciences; Department of Food Science, The Pennsylvania State University, University Park, PA, United States

Katherine D. Kinzler
Departments of Psychology and Human Development, Cornell University, Ithaca, NY, United States

Tanja V.E. Kral
Department of Behavioral Health Sciences, School of Nursing; Department of Psychiatry, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, United States

Julie A. Mennella
Monell Chemical Senses Center, Philadelphia, PA, United States

Kameron J. Moding
Department of Pediatrics/Section of Nutrition, University of Colorado Anschutz Medical Campus, Aurora, CO, United States

Alissa A. Nolden
Monell Chemical Senses Center, Philadelphia, PA, United States

Thomas G. Power
Department of Human Development, Washington State University, Pullman, WA, United States

Nathaniel R. Riggs
Department of Human Development and Family Studies, College of Health and Human Sciences, Colorado State University, Fort Collins, CO, United States

Kristin Shutts
Department of Psychology, University of Wisconsin – Madison, Madison, WI, United States

Marian Tanofsky-Kraff
Department of Medical and Clinical Psychology, Uniformed Services University of the Health Sciences, Bethesda, MD, United States

Alexis C. Wood
USDA/ARS Children's Nutrition Research Center, Baylor College of Medicine, Houston, TX, United States

PROLOGUE

What causes one child to have a seemingly insatiable appetite and another to be a picky eater? What is the best way to help children learn to like healthy foods? What role do parents play? Scientists have only recently begun to understand the answers to these fundamental questions. It is shocking to think that the development of children's eating behaviors was virtually unstudied at the time the US government published its first edition of the *Dietary Guidelines for Americans* in 1980 to foster healthy habits. Up to that time, nutritional research was primarily concerned with *what* children eat, focusing on nutrient requirements and preventing deficiencies. Disciplines such as developmental psychology were also interested in eating but primarily as a context for studying parent-child interactions, with little attention given to eating behavior per se. During the late 1970s and 1980s, a scientific literature began to emerge on appetitive behaviors, ranging from groundbreaking studies of taste acceptance and sweetness among infants to those on the self-regulation of short-term energy intake. But the work existed in small isolated pockets, conducted by only a handful of scientists around the world. And perhaps this would remain the case were it not for the pressing threat of the obesity epidemic that moved research on behavioral aspects of nutrition from the fringe into the spotlight. The recognition that rapid increases in obesity prevalence could not be explained by genetics alone turned the scientific community's attention, for the first time, to the role of the environment. This shift in thinking had the somewhat unexpected consequence of legitimizing research on behavioral aspects of nutrition and provided huge momentum to understand *how* healthy eating habits are established.

Pediatric Food Preferences and Eating Behaviors was written to highlight current areas of research in the study of children's eating behavior. Each chapter, written by leading researchers in the field, presents basic concepts and definitions, methodological issues pertaining to measurement, and the current state of scientific knowledge as well as directions for future research. Chapters are grouped along two organizing themes of development that have been the thrust of scientific inquiry to date—children's food preferences and the regulation of appetite. Research in these areas has evolved in parallel fashion over the past 30–40 years, moving from basic descriptive studies to understanding etiology and, more recently, how to effectively intervene. For instance, while Clara Davis is largely credited with conducting the seminal studies of self-selected intake and appetite regulation in the early 20th century, nearly a half century passed before the more controlled studies of caloric compensation began to emerge. Those studies set the stage for work in the 1990s and the following decade that identified a wider range of appetitive dimensions. During the 1990s and into the new millennium, research on children's eating behaviors grew rapidly with the recognition that individual differences in eating behavior were linked to important health outcomes like obesity. It was also during this time that work began to identify potentially modifiable influences on the developmental trajectory of appetite, such as parenting and the home food environment. In parallel, researchers began to pursue mechanistic studies to identify genetic and neurological bases of behavior, tapping into methodological advances such as GWAS and fMRI. More recently, the field has begun to intervene to nurture healthy appetites and eating behaviors. *Pediatric Food Preferences and Eating Behaviors* highlights these major advances and themes in understanding of the development of food preferences and appetite regulation.

Some of the most significant challenges in the field are integral to the exciting promise for the future of research on children's eating behavior. It was clear very early on that addressing scientific problems about eating behavior required perspectives outside of the traditional nutritional sciences mainstays such as nutrient metabolism, dietary assessment, and lifecycle nutrition. By its very nature, the study of children's eating behavior not only requires knowledge of nutritional needs, but also child development, family systems, parenting, and other social and structural environments that have bearing on the development of children's eating habits. The absence of a single disciplinary home has led to inconsistencies in language, theoretical approach, and methodology. *Pediatric Food Preferences and Eating Behaviors* highlights these challenges as well as the phenomenal diversity of perspectives that enrich the study of children's eating behaviors and have set the stage for major scientific advances in understanding how to nurture healthy eating habits for optimal health.

Jennifer O. Fisher

Julie C. Lumeng

Leann L. Birch

CHAPTER 1

Measuring Sweet and Bitter Taste in Children: Individual Variation due to Age and Taste Genetics

Julie A. Mennella[*], Alissa A. Nolden[*], Nuala Bobowski[*,†]
[*]Monell Chemical Senses Center, Philadelphia, PA, United States
[†]St. Catherine University, St. Paul, MN, United States

INTRODUCTION

The perception of the five basic tastes of sweet, bitter, umami, sour, and salt is mediated by taste receptors or ion channels in the periphery (primarily in the mouth)[1–3] and by multiple brain areas that are phylogenetically well conserved.[4] These senses function as gatekeepers, playing a critical role in determining whether to ingest a food or liquid and whether its nutrients gain access to the digestive tract. Although taste remains the top reason for purchasing decisions among adults, the importance of taste in food choice is most evident among children—they eat what they like and leave the rest.

In this chapter, we summarize the research on the ontogeny of taste that focuses on the contributions of both age and genetics to the sensitivity and hedonics of the taste system and its impact on behavior. Because of the lack of pediatric research on the relationship between a person's genes and his or her behaviors (i.e., genotype-phenotype relationships) as related to salty, sour, and umami taste perception, we limit this review to sweet and bitter taste phenotypes. We highlight the breadth of methodologies used to measure taste phenotypes in children, the limited number of taste receptor genes studied to date, and the convergence of findings from this line of scientific inquiry that reveal how children differ from adults, as well as how each child is a unique individual.

TASTE PHENOTYPES: HOW TO MEASURE TASTE IN CHILDREN

Psychophysical studies on taste provide data relevant to two separate aspects of taste sensation: the *sensitivity* of the system (how much of a sensation is detected) and the *hedonic valence* of the sensation (how much that sensation is liked or disliked).[5] The psychophysical method used when the participant is a child varies depending on the objective of the study, the dimension of taste of interest, and the age and thus cognitive and language abilities of the child.

Pediatric Food Preferences and Eating Behaviors
https://doi.org/10.1016/B978-0-12-811716-3.00001-4

While there is no shortage of psychophysical tools purported to measure taste preferences among children,[6] few have been systematically tested for validity or age appropriateness.[7,8] In what follows, we describe the methods (often referred to as tools) used to measure taste preference or taste sensitivity (detection) among children. This is not a complete listing of all methods or all research studies on this topic but rather represents the methods used to determine whether children differ from adults and whether they differ from one another based on their taste genes (for more complete listing, see Mennella and Forestell[7]). Some of these methods were adapted or modified from those used in adults, whereas others were developed specifically for use in children. When available, we provide evidence of measurement validity (i.e., degree to which the tool measures what it purports), criterion-related internal validity (i.e., degree to which the tool relates to other outcomes within the study), and retest reliability (i.e., degree of repeatability of the measurement over time).

As shown in Table 1.1**,** in some studies the child is simply asked whether they taste something, or his or her liking for a particular taste or sensitivity to sweetness or bitterness is inferred from dietary recall records that are typically completed by parents or caregivers. In other studies, the methodological approach is more direct in measuring responses to solutions or foods that are tasted by the child (with or without swallowing) or to tastant-soaked filter paper disks that are placed on the child's tongue. Typically, the child is given time to acclimate to the testing room or is tested in a familiar setting,[20,22,24] and in some studies, testing occurs after a 1-h fast.[10,26]

The most studied taste phenotype, which is often regarded as one of the most studied human traits,[27] is the ability to taste compounds containing a thiourea (N—C═S) moiety, such as propylthiouracil (PTU or PROP) and its chemical relative phenylthiocarbamide (PTC). The initial discovery, made in 1931 by A. L. Fox, an organic chemist working at DuPont,[28] was serendipitous: some PTC crystals were spilled in the laboratory, and some became airborne; Fox and collaborators noted and later verified through experimental studies that, while many perceived bitterness from the airborne chemical, Fox did not.[29] Eight decades after the initial suggestion that human variation in PTU and PTC taste perception could be genetically linked,[30,31] the molecular basis was elucidated: the *TAS2R38* gene[32–37] that encodes for the taste receptor protein underlying personal variation in taste detection thresholds (i.e., the lowest concentration that can be detected by the person) for PTC and PTU was discovered.

Detection Thresholds

The methods that have been used on children to measure detection thresholds range from those specifically geared for children (e.g., forced-choice ascending-concentration categorization procedure) to those used on adult patients in the clinic (e.g., forced-choice staircase procedure).

Table 1.1 Partial listing of methods used to measure taste detection thresholds, taste intensity, and taste preferences (hedonics) among children

Taste dimension	Name of method	Description of method	Reference
Taste detection threshold	Forced-choice, ascending-concentration categorization procedure	Children taste (without swallowing), in succession, water and then three increasing concentrations of bitter tastant. If the solution tastes like "water" or "nothing," they give the sample to Big Bird. If the sample tastes "bad," "yucky," or "bitter," they give it to Oscar the Grouch. (Some studies also recorded whether the child made a facial expression of distaste during tasting.) Grouping is based on the concentration of the first sample, if any, given to Oscar the Grouch.	Anliker et al.[9]; Mennella et al.[10]
	Two-alternative, forced-choice staircase procedure	Children taste pairs of solutions, one of which is water and the other contains a tastant, after which they point to the solution that has a taste. Tastant concentration in the next pair is increased after a single incorrect response (water is chosen) and decreased after two consecutive correct responses. Detection threshold is the mean of the log values of the last four reversals.	Joseph et al.[11]; Bobowski et al.[12]
Taste intensity	General labeled magnitude scale (gLMS)	During training, children are asked to imagine the loudest sound they have ever heard and to use that sound as the top anchor on the 100-point scale with the bottom anchor labeled 'no sensation' and top anchor labeled 'strongest imaginable sensation of any kind,' as well as labels for intermediate sensations (e.g., weak, moderate, very strong). They then rate four solutions containing increasing concentrations of sucrose on the gLMS. Children who correctly ranked the sucrose solutions in order of intensity then rate taste stimuli using the scale.	Feeney et al.[13]

Continued

Table 1.1 Partial listing of methods used to measure taste detection thresholds, taste intensity, and taste preferences (hedonics) among children—cont'd

Taste dimension	Name of method	Description of method	Reference
	General visual analog scale (gVAS)	During training, children are told the leftmost end of the horizontal scale represents no sensation and the rightmost end the most intense sensation, equivalent to the loudest sound or brightest light ever experienced. Children rate the intensity of a whisper and a shout on the scale. If they correctly place whisper, shout, and loudest sound in order from least to most intense, they then rate taste stimuli using the scale.	Timpson et al.[14]
	Rank-by-elimination task	Children taste individual solutions or foods in randomized order and indicate which sample or samples are most intense. That sample(s) is removed and the child repeats the task with the remaining samples. The procedure continues until rank order is established from most to least intense (e.g., sweetness, sourness) or most to least preferred.	Liem and Mennella[15,16]
	Rank order intensity task	Children taste individual solutions or foods in randomized order and group stimuli into two or more broad categories (e.g., 'least sweet', 'most sweet'). Within each category, they then rank stimuli, resulting in an overall ranking from least to most intense (e.g., sweetness).	De Graaf and Zandstra[17]
Taste hedonics	Hedonic face scales	A visual scale that contains 3 faces (i.e., 3-point facial hedonic scale) or more displaying emotions that range from frowning to smiling faces and a neutral face in the middle position or contains only verbal descriptors. Children taste individual solutions and point to the face on the scale that best	Bobowski et al.[18]; Bobowski and Mennella[19]; Suomela et al.[20]; Negri et al.[21]

		represents how it tastes. (In some cases, investigators score intensity of children's facial reactivity during tasting on a category scale.)	
	Hedonic face scale followed by ranking within each category	Children taste individual solutions or foods and place each sample in front of one face on a 3-point hedonic face scale that best represents how it tastes. Then children order solutions within each face category, from most liked to most disliked, providing an overall ranking of samples from most to least preferred.	Birch et al.[22]; De Graaf and Zandstra[17]; Liem and De Graaf[23]
	Rank-by-elimination task	Children taste a number of individual solutions or foods in randomized order and then point to the sample most liked. That sample is then removed and the child repeats the task with the remaining samples. The procedure continues until a rank order is established from most to least liked.	Birch[24]; Liem and Mennella[15]
	Forced-choice, paired-comparison, tracking procedure	Children are presented with pairs of solutions. The child tastes each solution and indicates which one tastes better. Each subsequent pair contains the selected concentration and an adjacent stimulus concentration. Tasting continues until criterion is met. The task is then repeated with pairs presented in reverse order (i.e., the lower concentration within a pair is presented first in series 1 and last in series 2). The geometric mean is the estimate of most preferred level of sweetness. (In some cases, children were asked to recall their most favorite cereals or beverages to relate to sweet preference.)	Mennella et al.[10]; Mennella and Bobowski[25]

Forced-choice, ascending-concentration categorization procedure. In 1981, Anliker, Bartoshuk, and colleagues[9] developed a forced-choice procedure to determine the lowest concentration of PTU that could be detected (i.e., detection threshold). The method was adapted by Mennella and colleagues[26,38,39] to determine whether variation in taste genetics explains variation in PTU detection thresholds among individuals as young as 3 years. Only a small percentage of children (~5%) did not understand or finish the task.[26,38,39]

After a 1-h fast and 15–30 min acclimation to the room and study personnel, participants taste (but do not swallow), in ascending order, water and three different concentrations of PTU solutions (56, 180, and 560 μM), rinsing their mouths with water before and after each tasting (Table 1.1). They are told that, if the solution tastes like water, to give it to a stuffed Big Bird™ toy (a likable, well-known television character puppet), but if it tastes "yucky" or bitter, they should give it to another well-known puppet, Oscar the Grouch™, so that "he can throw it in his trash can." Participants were categorized into one of four groups based on the first sample (56, 180, or 560 μM) given to Oscar the Grouch or if all samples are given to Big Bird (none tasted bitter).

In some studies, researchers also recorded whether the participant displayed any facial expression of distaste (e.g., grimace) to assess internal validity or superiority of the outcome measure.[26] Participants were categorized into one of four groups based on the first sample, if any, that the child displayed a facial expression of distaste (e.g., grimace).[26] Of interest, categorization based on facial expression was less reliable and overestimated the percentage of children that were bitter sensitive to the taste of PTU than categorization based on what sample was given to Oscar the Grouch.[26] Several studies retested a subset of the children several months later and found that children's detection thresholds were reliable over time.[26,38]

Two-alternative, forced-choice staircase procedure. Detection thresholds can also be determined by a two-alternative, forced-choice staircase procedure originally used in adult clinic populations,[40] but this task can be longer and more complicated than the forced-choice categorization method described previously. To date, children as young as 7 years have understood and completed the task.[11,12] Very few children did not complete or understand the task (1%–3%[11,12]), but whether children younger than 7 years can use this method reliably requires further investigation.

This method involves children (or adults) tasting a range of solutions (i.e., 5.6×10^{-5} to 1.0 M in quarter-log steps) to determine the lowest concentration of a tastant that the person can detect relative to water. After acclimation to room and personnel and after not eating any foods for an hour, participants are presented with pairs of solutions to taste. One sample within each pair is water and the other contains the taste stimulus under study (e.g., sucrose,[11] salt,[12] monosodium glutamate[12]). For the first pair offered to the child during the sucrose detection threshold test, the concentration of the taste stimulus is 1.0×10^{-3} M (see Refs. 11, 12 for more detailed methods). After tasting both solutions in randomized order, without swallowing and rinsing between tastings, participants are instructed to point to the one that has a taste. The concentration of the taste stimulus presented in the next pair increases after a single incorrect response (i.e., participant points to water, not taste solution, as having a taste) or decreases after two consecutive correct responses. The task continues until the participant completes four reversals (i.e., an incorrect response followed by two correct responses or vice versa), provided there are no more than two dilution steps between two consecutive reversals, and the reversals do not form an ascending pattern such that positive and negative reversals are achieved at successively higher concentrations. The participant's detection threshold is the mean of the log values of the last four reversals. To our knowledge, no retest reliability has been determined to date in children.

Taste Intensity

Ranking methods. When the task is to assess a participant's ability to discriminate liquids or foods based on the intensity of a taste, researchers can use methods in which the children rank the items based on a taste quality or on liking.[15–17] For example, children as young as 5 years are presented with a series of four or five solutions or foods that differ only in the concentration of a given tastant (e.g., sucrose,[16,17] citric acid[15]). In some studies, children are asked to taste each stimulus and then point to the sample that tastes strongest. That sample is then removed and the participant repeats the task with the remaining samples until a rank order of intensity is established from most to least intense (i.e., rank by elimination method). In other cases, after tastings, children group stimuli into one of two broad categories (e.g., "most sweet", "least sweet") after which they rank stimuli within each category, which in turn results in an overall ranking from least to most sweet or least to most preferred (i.e., rank order intensity method).[15,17] One study which used this method conducted a check on internal reliability and validity by presenting each child in randomized order with the most (0.25 M citric acid) and least (0) sour tasting, sweetened gelatin.[15] Children were given these taste stimuli in random order to retaste and to indicate whether it tasted sour or sweet. There was strong agreement between children's ability to rank stimuli in order of increasing taste intensity and to correctly identify the taste quality during the retest, even among those as young as 5 years of age.[15]

Scaling methods. Scaling methods, which are cognitively demanding, are frequently used tools to quantify perception in adults. For taste, the gold standard scaling method is the general labeled magnitude scale (gLMS), which has been validated for use in adults and shown to be superior to other rating scales (e.g., 9-point scales) when comparing taste sensations among individuals.[41–43] Further, retesting of adults revealed gLMS ratings for PTU and another bitter tasting medicine are a stable phenotype that is reliable over time.[44,45] On the gLMS, the vertical scale ranges from 0 to 100, with adjectives at the bottom anchor ("no sensation") and top anchor ("strongest imaginable sensation of any kind"), as well as adjectives placed along the scale logarithmically ("barely detectable," "weak," "moderate," "strong," "very strong").[41,43,46] The top anchor allows participants to rate the intensity of the taste within the context of all things, including nontaste experiences, which in turn allows valid across-group comparisons. While the general visual analog scale (gVAS) is based on the same principles as the gLMS, this scale contains only the anchors and no adjectives along the horizontal 10 cm scale.

To our knowledge, only a few studies on taste-genotype relationships had children between the ages of 7 and 13 years rate taste stimuli on either a gLMS or a gVAS.[13,14,47] In two of the studies, training was provided. Before rating on a gLMS,[13] children were told to imagine the loudest sound they had ever heard, and then to imagine something even louder, explaining that the loudest noise imaginable would be the top anchor of the scale. Children then tasted four concentrations of sucrose (0.15, 0.29, 0.44, 0.58 M) in randomized order and rated taste intensity of each on the gLMS.[13] Of the 525 total children enrolled, only 1% were excluded because they were unable to properly rate these stimuli in order of concentration. A similar training session was provided for the horizontal gVAS,[14] but here children were told that the leftmost end of the scale represented no sensation and the rightmost end the most intense sensation, equivalent to the loudest sound or brightest light they had ever experienced. The experimenter then had the children rate a whisper and a shout, making sure the ratings were placed on the scale in order of whisper, shout, and loudest sound. While these training sessions may provide some indication of whether the child can use these scaling methods to rank order intensity, it does not provide evidence that they understood differences in the scaling and labels (other than equating a whisper to no or little sensation). However, one study retested children 1 month later and found that 10-year-old children's gVAS ratings of PTU were reliable over time.[14] More research is needed to determine the lower age limit at which children can perform these more sophisticated scaling methods and, in particular, understand the concept of the anchor(s) in the scale. Box 1.1 summarizes methods used to measure taste detection and intensity.

BOX 1.1 Section Summary

- Forced-choice, ascending concentration detection threshold methods: pairs of solutions of specific concentrations of a tastant are presented to the child in ascending order to determine the lowest concentration at which a particular taste sensation can be detected.
- Ranking methods: a number of taste stimuli (solution, food) are presented to the child who ranks them based on the intensity of a tastant or on liking.
- Rating/scaling methods: a number of taste stimuli (solution, food) are presented individually to the child who uses a numerical or description scale to rate the strength of a particular taste sensation.

Taste Hedonics

For people of all ages, but especially children, a general rule is that it is easier to measure hedonics (palatability) than detection.[48] The methods used to measure taste hedonics vary from evaluating one taste stimulus at a time to a series of paired-choice comparisons to determine the level of a taste most preferred. To clarify, liking provides a measure of hedonic response to a single stimulus and is measured using methods such as the hedonic face scale, whereas preference provides a measure of how much a person likes a given stimulus relative to another and is measured using methods such as the rank-by-elimination task and the forced-choice, paired-comparison tracking procedure described herein.

Hedonic face scale. Perhaps the most popular method for use with children is the hedonic face scale, a categorical scale made up of a range of face figures (e.g., 3–9 faces[6]) that depict ranges in emotion from frowns to smiles, with a neutral face typically placed in the middle of the scale. (In one case, the children were presented with a scale that had only the verbal descriptors signifying the emotion, not the faces.[20]) Depending on the orientation of the scale, its top and bottom (or right and left) anchors represent the most extreme frown and smile. In brief, children as young as 3 years are instructed to taste a liquid or food and then to point to the face that best represents how the liquid or food tastes to them.[24] From these data, their taste responses are categorized.

Some investigators have assessed whether children are capable of using the range of hedonic face scales by including other taste stimuli that vary in taste quality and hedonic valences.[19] For example, when evaluating children's ratings of liquids containing different nutritive (e.g., sucrose) or nonnutritive (e.g., sucralose) sweeteners on 5-point and 3-point hedonic face scales, investigators included others solutions containing varying amounts of potassium chloride, because it does not taste sweet and adults often describe it as tasting bitter and metallic.[49] While children used the smiley faces on the scale to describe their liking for sweeteners, they used the frowning faces to describe their dislike for potassium chloride, providing evidence that these children could use the entire scale and that they understood the difference between smiling and frowning faces as they relate to taste hedonics.

While this categorization of the test stimuli can be the final outcome measure, some researchers utilized the hedonic face scale as part of a rank-by-elimination task to determine rank order preference.[22] That is, after children selected the face that best represented their liking for a series of taste stimuli, they were then asked to order the stimuli within each face category from most to least liked, providing an overall ranking of samples from most to least preferred.[17,22,23] Rank order preferences of three versions of a food (i.e., tofu) that differed in taste (i.e., plain, sweet, salty) were reliable over time, even among children as young as 3–4 years.[22] Among 8- to 10-year-olds, how they rank ordered their preferences for flavored beverages containing varying levels of sucrose significantly related to how they rated the taste of these beverages on a 5-point hedonic face scale. That hedonic ratings were positively related to how much of the beverage the child drank provided evidence of measurement and criterion-based validity.[17]

Two-series, forced-choice tracking procedure. To determine the level of a particular tastant most preferred by an individual, researchers at Monell Chemical Senses Center developed a two-series, forced-choice tracking procedure which has been used in children 3 years and older.[10,50,51] First developed to determine the most preferred concentration of salt among children,[50] the Monell forced-choice, paired-comparison, tracking procedure was adapted and validated for the NIH Toolbox to measure the most preferred level of sucrose among adults.[10,25]

In brief, this psychophysical tool involves presenting participants with pairs of solutions that differ in concentration. For example, the five concentrations of sucrose used to determine most preferred level of sweetness are 0.09, 0.18, 0.35, 0.70, and 1.05 M (which are equivalent to 3%, 6%, 12%, 24%, and 36% wt/vol). The first pair presented is from the middle range of concentrations (0.18 and 0.70 M). The child tastes each solution in randomized order and then indicates which one tastes better. Each subsequent pair of solutions presented contains the concentration selected by the child in the preceding pair and an adjacent concentration stimulus, with this pattern continuing until the child either chooses the same concentration when paired with both a higher and a lower concentration in two consecutive pairs or chooses the highest or lowest concentration twice consecutively. After a 3-min break, the task is repeated but stimulus pairs are presented in reverse order (i.e., the lower concentration is presented first in series 1 and the higher concentration is presented first in series 2), to control for position bias. The geometric mean of the concentrations selected during the two series provides the estimate of most preferred level of sucrose, a measure that over the years has provided insight into individual differences, including age,[10] race/ethnicity,[10,52] family history of addiction and depression,[53] weight status,[19,54] and taste receptor genotype[26] (see "Genetics of Sweet and Bitter Taste").

Because this method consists of two series that controls for position bias, it enables researchers to determine objectively whether the child understands the task or is responding at random (measurement validity).[10,25] For example, if a child tended to always point to the solution on his or her right, the level most preferred in the first series would be 3–4 steps away from most preferred in the second series. Using this criteria, only 6% of the children did not understand or complete the task.[10,26,53,55] However, while this method has been used on 3-year-old children to measure salt preference,[50] the vast majority of studies conducted to date have been on children 5 years of age and older.

For those children who understood the task, there was significant reliability in the level most preferred in series 1 with series 2, providing evidence of internal consistency. Further, the level of sweetness most preferred in water was significantly related to