Food Quality and Preference 58 (2017) 61–70

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

The magic water test. An affective paired comparison approach to evaluate taste sensitivity in pre-schoolers

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ARTICLE INFO

Article history:
Received 4 November 2016
Received in revised form 9 January 2017
Accepted 9 January 2017
Available online 10 January 2017

Keywords:
Children
Sensory sensitivity
Affective approach
Paired comparison test
Basic tastes

ABSTRACT

Children in pre-school age present a limited cognitive development, a restricted vocabulary and a short attention span, which do not allow conducting classical taste sensitivity measures as developed for adults. The aim of this study was to develop and validate an age-appropriate protocol for sensitivity testing of the five basic tastes with pre-schoolers. One hundred and forty children aged 3–4 years (mean age 46.3 months, SD 3.4) performed a paired comparison task consisting of discriminating water from "magic water" by relying on their affect. In order to accommodate the age group, the task was gamified and did not require verbal responses. Sweet (sucrose, ranging from 0.94 to 4.32 g/l), sour (citric acid monohydrate, 0.20–0.38 g/l), umami (monosodium glutamate, 0.17–0.49 g/l), salty (sodium chloride, 0.34–0.98 g/l), and bitter (quinine hydrochloride dihydrate, 0.0014–0.0038 g/l) water dilutions were tested at four levels. Subsets of about 20 children per taste participated in retest sessions. Individual sensitivity scores were derived in two manners, following the experimenter's success criterion (water with taste is classified as magic) and the child's criterion for "magic water" (children's individual magic-labelling strategies). Results show that the protocol was highly engaging, that the children performed the task consistently, and that the children's performances were not dependent on cognitive level differences, thus validating the protocol for this study. On average, the children were clearly more sensitive to sour stimuli than to sweet and bitter stimuli, suggesting that the selected dilutions were not equivalent across tastes. Different sensitivity distributions of the children were obtained across taste modalities and scoring criteria. The key elements of an age-appropriate protocol for pre-schoolers are discussed.

1. Introduction

Taste sensitivity can be expressed as the ability to perceive a taste (Lanfer et al., 2013). It is a determinant of preferences for the basic tastes (Lanfer et al., 2013) and has been found to impact food choice and liking (Duffy, Peterson, Dinehart, & Bartoshuk, 2003; Hartvig, Hausner, Wendin, & Bredie, 2014; Hayes & Duffy, 2008; Masi, Dinnella, Monteleone, & Prescott, 2015). Sensitivity for the five basic tastes has been comprehensively studied in adults (see e.g. Bartoshuk (1974), Bitnes, Martens, Ueland, and Martens (2007), Chang, Chung, Kim, Chung, and Kho (2006), Hoehl, Schoenberger, and Busch-Stockfisch (2010), Kauer, Pelchat, Rozin, and Zickgraf (2015)), but less is known about young children's taste sensitivity. According to Mennella, Spector, Reed, and Coldwell (2013), children generally live in a different sensory world than adults do. In particular, several cross-sectional studies investigating sweet taste have demonstrated a variation in sensitivity for sucrose throughout the lifespan. Thus, an increase in sucrose sensitivity has been reported from age three until age six (Visser, Kroeze, Kamps, & Bijleveld, 2000) as well as an increase in perceived intensity from childhood to young adulthood (De Graaf & Zandstra, 1999). In addition, the perception of suprathreshold sucrose stimuli has been found to reach maturity at eight years old (James, Laing, Jinks, Oram, & Hutchinson, 2004) even though the gustatory system is still maturing beyond this age (James, Laing, & Oram, 1997), highlighting the complexity of the development of sensitivity for sucrose. For bitter taste, the literature seems to indicate a stronger stability in sensitivity through life. Thus, studies found sensitivity for 6-*n*-propylthiouracil (PROP) to be similar between early readers and adults (Anliker, Bartoshuk, Ferris, & Hooks, 1991), and similar for female pre-teens and adults (James et al., 1997). Visser et al. (2000) tested three to six year old children for sensitivity to urea and found large inter-individual variations, with detection thresholds varying from 3.75 to 240 mmol/l (mean threshold 59.4 mmol/l). To our knowledge, there is a lack of litera-

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http://dx.doi.org/10.1016/j.foodqual.2017.01.003
0950-3293/

ture about children's taste sensitivity with regards to particularly sourness, but also saltiness (Goldstein & Leshem, 2014; Knof, Lanfer, Bildstein, Buchecker, & Hilz, 2011; Lanfer et al., 2013), and umami (Knof et al., 2011; Lanfer et al., 2013). All in all, the development of taste sensitivity in preschool years is still vastly unknown for all the different basic tastes.

It is difficult to directly compare results from studies investigating children's taste sensitivity with results from similar studies on adults, as methods used with adults may not be suitable for children. The different results obtained when testing children could be influenced by different cognitive, verbal, and fine motor skills rather than a difference in taste sensitivity (Guinard, 2001; Nicklaus, 2015; Popper & Kroll, 2005; Varela & Salvador, 2014). According to Laureati, Pagliarini, Toschi, and Monteleone (2015), the keys to successful children testing rely on the usage of procedures appropriate to the child's level. It is also important to ensure that the child feels comfortable in the test environment. Thus, children under reading age need to be tested individually and preferably in the presence of a familiar adult. As young children like confirming what adults say, double-blind testing should be conducted to ensure that the children are not involuntarily guided in their answers by the experimenter (Guinard, 2001; Mennella et al., 2013). Further, children generally have a short attention span, and testing should be divided into short sessions (ASTM, 2013; Mennella et al., 2013; Popper & Kroll, 2005). To heighten the interest of the children and increase their participation rate, testing could be structured as a game (Knof et al., 2011). This is possible with children as young as two years old, as they can understand and engage in pretend speak (Friedman, Neary, Burnstein, & Leslie, 2010).

One of the tools from developmental psychology that exists to evaluate developmental differences in preschool children is the Ages and Stages Questionnaire (ASQ) (Squires, Potter, & Bricker, 1999). The ASQ is an age-related parent-completed questionnaire that measures the child's development of communication, gross motor, fine motor, personal-social, and problem solving skills. This measure is relevant when working with a sample of children of limited age-span, because children present large differences in their skills also within a specific age group and individual development is often more important than chronological age (ASTM, 2013). In particular, the literature reports large differences in verbal capacity among young children; moreover shy children could fail to speak to unknown adults (ASTM, 2013; Ford, Sladeczek, Carlson, & Kratochwill, 1998). In a study on odour thresholds, Monnery-Patris, Rouby, Nicklaus, and Issanchou (2009) reported the importance of verbal fluency when evaluating odour identification in children aged 4–12 years. Also flavour labelling has been found to be associated with higher linguistic abilities in children between three and six years of age (Lumeng, Zuckerman, Cardinal, & Kaciroti, 2005), and preschool children can have trouble understanding the concept of analytical labels such as "sweeter than" (Guinard, 2001; Liem, Mars, & De Graaf, 2004). To minimise the impact of different verbal abilities between the children, sensitivity tests should therefore as far as possible be non-verbal. Similarly, tests should generally try to reduce the influence of cognitive differences on the results. According to the American Society of the International Association for Testing and Materials, children 3–5 years old can successfully perform paired comparisons, as well as limited sorting and matching techniques using pictures (ASTM, 2013). However, Liem et al. (2004) reported that their analytical approach to sensitivity testing based on rank-order and paired comparison tests was too challenging for 4-year old children.

Affect is defined as the *experience of feeling or emotion* (Hogg, Abrams, & Martin, 2010). Affective approaches measure intuitive responses, as opposed to analytical responses, and should be preferred when testing young children as they depend less on cognitive encoding (Zajonc, 1980). Affective procedures also heighten the involvement of the participants (Boutrolle, Delarue, Köster, Aranz, & Danzart, 2009; Zajonc, 1980), which is important when testing a group with a short attention span, and who are not motivated by contribution to science and/or monetary rewards. In their study on taste sensitivity in 3–6 year old children, Visser et al. (2000) developed a procedure where detection thresholds for sucrose and urea were measured by a staircase method and aversion to urea was assessed hedonically, using drawings of facial expressions. They reported that young children would not complete a paired comparison test if the difference in the first pair was too small, and that testing of bitterness should preferably be performed last in order to avoid early withdrawals from the experiment due to aversion (Visser et al., 2000; see also Beauchamp & Mennella, 2009; Mennella et al., 2013). Finally, they concluded that "it is possible to study taste perception in very young children if their age is taken into consideration in developing the test procedure. Valid data can be obtained if the procedures are short, easy to understand and intrinsically motivating" (Visser et al., 2000).

Taste sensitivity in preschool children has seen little research because this group is more challenging to study than older children and adults, and there is a lack of adapted testing procedures that work well for this age group (Knof et al., 2011). Mennella, Yanina Pepino, and Reed (2005) tested bitterness sensitivity in 5–10 year old children using dolls of well-known television characters. The test was based on hedonic aversion for bitterness, where the child should give the water samples to the likeable character and the yucky ones for the trash. Although the procedure was successful, it is not transposable to likeable basic tastes. In a recent study, Knof et al. (2011) developed a procedure for taste threshold testing of four basic tastes (sweet, salty, bitter and umami) with children aged 3 to 10 years. The children performed an analytical sorting task of taste dilutions either as "water" or "not water". These authors reported that the test was adequate for children 6–10 years, yet the method could not be validated for younger children (Knof et al., 2011).

The aim of this study was to develop and validate an experimental protocol for taste sensitivity testing that addresses the specific developmental and emotional characteristics of preschoolers. More specifically, this paper introduces an affective approach to paired comparison tests for basic taste sensitivity testing in pre-schoolers, and reports sensitivity testing results for the five basic tastes in 3–4 year old children.

2. Materials and methods

2.1. Pre-study and protocol development

The present study is based on a comprehensive pre-study, which aimed at generating a protocol for taste sensitivity testing in children 3–6 years old. The pre-study was conducted in several phases, and included 43 children in total with a mean age of 4.4 years (SD 0.95; age range 3–5 years). Paired comparison tests of plain water versus water with varying concentrations of sweet (sucrose) or sour (citric acid monohydrate) tastes were used. The taste concentrations were based on the ISO-standard 3972 (ISO, 2011) and the selection of four appropriate concentration levels per basic taste was adjusted along the phases of the pre-study. The protocol that was developed involved a story-telling session about a fairy who drank magic water of different tastes. During testing, the children were asked to place the cups with magic water on the picture of a fairy. The first outcomes of the pre-study indicated that under this protocol, the children were engaged in the test and the participation rate was high. Children were able to reli-