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The role of taste (sugar, salt) on the regulation of food intake in a single exposure

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Table of contents

Executive Summary

Background: Children's consumption of free sugars exceeds public health recommendations. However, it is unclear what the relation is between exposure to sweetness in childhood, and children's liking or intake of sweet-tasting food and beverages.

Objective: We aimed to provide an overview of the current evidence regarding the effect of sweet taste exposure on sweetness liking and intake of sweet foods in children.

Design: Systematic searches were conducted to identify relevant studies. These studies were tabulated according to study design, early or later exposure and short-term versus longer-term effects of (repeated) exposure to sweetness in childhood and sweetness liking or intake of sweet food and beverages in children.

Results: Fourteen studies met our inclusion criteria, comprising of 12 longitudinal cohort studies and two controlled experiments. The studies varied greatly in research design, participants age, exposure time, exposure assessment, sweetness liking, intake assessment and outcome measure. The results provide some evidence for increased sweetness liking after early exposure in infancy to sweet taste for similar flavor profiles. For more complex flavors and exposure later in childhood, results were inconsistent. The two controlled experiments showed that repeated exposure to products with a higher sweetness intensity may increase sweetness liking and preference, at least in the short-term immediately after the intervention.

Conclusion: The evidence regarding the relationship between sweetness exposure and sweetness liking or the intake of sweet products is heterogenous and scarce. Some findings indicate that early exposure in infancy to sweet taste may increase sweetness liking for similar flavor profiles. There is a strong need for more controlled experimental studies to better understand the influence of sweetness exposure on sweet liking and intake.

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The effect of sweet taste exposure on sweetness preferences and intake of sweet foods in children: A literature review

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Abstract

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Keywords: sweet taste exposure, sweetness liking, intake of sweet foods and beverages, infants, children

1. Introduction

Poor dietary habits negatively influence health- and wellbeing, and childhood dietary habits are primarily influenced by food preferences. Preferences are influenced by taste and flavor liking and remain from early childhood to old age which puts children's food experiences in the spotlight (Beckerman et al. 2017). A significant part of this nutritional experience is determined by sugary foods and beverages that are regularly consumed by children worldwide (Dereń et al. 2019; Ventura & Mennella, 2011). Eighty percent of two to three year-old children have a daily intake of sweetened beverages and desserts (Fox et al., 2010). As a result, sugar makes up 15.6% to 25.6% of children's daily total energy intake in Europe (Azaïs-Braesco et al., 2017). This is alarming as the maximum intake of free sugars (i.e. added sugars and naturally occurring sugars in fruit juices and fruit juice concentrate) should stay below 10% of children's daily energy intake according to the World Health Organization (WHO, 2015).

As children's food consumption is largely determined by food preferences which in turn are dependent on taste – and flavor preferences, it is important to understand why sweetness is such a globally liked flavor (Schwartz et al. 2011; Yuan et al.2016). For this, we should first look into biological reasons, and also consider environmental factors. Indeed, sweetness preferences are rooted in humans' nature, as we have an inborn preference for sweet taste (Beauchamp & Mennella, 2009; Ventura & Worobey, 2013; Mennella & Bobowski, 2015). This is because the body associates sweetness with energy-rich foods and easy to digest carbohydrates that are needed for growth and development after birth (Beauchamp, 2016). A further function of this innate sweetness preference is to attract newborns to their mother's breast milk as they are already able to detect and even distinguish between different levels of sweetness directly after birth (Ventura & Mennella, 2011). When exposed to a sweet flavor, an increase in heart rate and relaxed facial expressions are detectable which is attributed to the activation of brain areas

associated with reward (Ventura & Mennella 2011). Therefore, the liking of sweet-tasting food and beverages in newborns and infants is initially influenced by biological functions. However, with increasing age, the preference for sweet taste evolves over time and becomes more and more determined by experience and learning (Forestell 2017).

Several studies provide evidence that children prefer a higher level of sweetness than adolescents and adults (Mennella & Bobowski 2015; Mennella & Pepino 2005; Liem & Mennella 2002; De Graaf and Zandstra 1999; Ventura and Mennella 2011). Children's sweetness preference may be influenced by early experiences with a variety of sweet-tasting foods and beverages, and the interconnectivity of biological, social and environmental factors (Ventura & Worobey, 2013; Appleton et al, 2018). There is robust evidence that children's early exposure to, and intake of, foods and drinks with certain flavors enhances their liking for these flavors (Ventura & Worobey, 2013; Spill et al. 2019). However, this research has predominantly focused on novel and potentially disliked foods, such as bitter tasting vegetables, and therefore other tastes than sweetness. There has been limited research on whether a similar association exists between exposure to and liking of more palatable foods, such as sweet foods, for which liking does not need to be learned. Thus, children's development of liking sweet foods may differ compared to disliked flavors due to children's innate preference for sweetness (Jackson et al., 2020). Nevertheless, the preference for sweetness may still be influenced and perhaps even increased through repeated exposure to sweet stimuli (Nicklaus et al. 2005). This repeated exposure already begins in the period of milk-feeding due to sweet-tasting breast and formula milk. Further, it continues during the whole first year of life, as sweet tastes are the dominating taste properties children are exposed to during that period (Schwartz et al. 2011; Nicklaus et al., 2019). To illustrate, the dietary exposure to sweet taste and fattiness both

increase during the first year of life with the introduction of complementary foods in the diet, but exposure to sweetness increases more rapidly than exposure to fattiness (Yuan et al., 2016).

Children's exposure to sweet-tasting foods and beverages is also influenced by parents, as they manage young children's home food environment. Furthermore, parental strategies such as restriction or using foods as rewards are often used in combination with sweet products. How restrictive feeding practices are related to dietary exposure to sweet-tasting products and sweetness preferences in children is, however, unclear. Restriction may result in a decreased intake of sweet foods and beverages at home, but can increase children's consumption of sweet foods when they are in an unrestricted situation (Jansen et al, 2007). Moreover, as sweet foods and beverages are often used as a reward (Appleton et al. 2018) or to calm children down due to pain-reducing effects of sweetness (Menella & Bobowski, 2015), children are repeatedly exposed to sweet taste. A high consumption of free sugars in the diet has been associated with childhood overweight and obesity (Malik et al. 2013; Keller & Bucher Della Torre 2015). Especially consumption of sugar-sweetened beverages seems to be an important contributor to this association (Luger et al., 2017; Malik et al. 2013). Yet, the question arises whether not only the intake of free sugars in the diet should be reduced, but also the exposure to sweet taste (Appleton et al., 2018). A recent review investigating the relationship between sweet taste exposure and subsequent preferences and intake showed that the evidence is equivocal regarding the presence and possible direction of a relation (Appleton et al., 2018). However, this review was not focused on children in particular. In order to give direction to future research among children in this area, there is a need to get an overview of what is known about the topic. So, this narrative literature review aims to put light on the status quo of the relationship between sweetness exposure and changes in sweetness liking and its subsequent consequences for the intake of sweet foods and beverages in children.

2. Methods

A literature search was conducted in the first trimester of 2021 using the electronic databases Pubmed® and Google Scholar® to map the status quo of scientific findings regarding the effect of sweet taste exposure on changes in sweetness preferences and intake of sweet foods and beverages in children. To cover both sweetness preferences and sugar intake, two different literature searches were conducted.

In the first literature search, the following keywords were used: 1) Sweetness preference (sweetness preference OR sweet preference OR sweet liking OR sucrose preference) AND 2) Study population (children OR infants OR toddlers OR babies) AND 3) exposure (sweet taste exposure OR sweet food exposure OR sweet beverage exposure OR sweet food intake OR sweet drinks intake)). For the second literature search, the same sets of keywords as used in the first search were included, however, sweetness preference was exchanged with keywords covering the intake of substances associated with sweet taste (sugar intake OR sucrose intake OR sugar sweetened beverage intake OR sweet food consumption). Citations in the found publications were used as a further source to find relevant scientific literature.

For a scientific paper to be included in the literature review, the title or abstract had to cover at least two of the three search terms. Only human studies and research published in English were taken into account. Studies focused on adults or animals were excluded. After exclusion of duplicates, and irrelevant titles, 14 papers were considered relevant to the literature review.

All data were investigated using a narrative synthesis. Further analysis, e.g. meta-analysis, were not conducted due to insufficient papers using the same study design. Papers were tabulated according to their main characteristics: study design, age of exposure (early: 0-2 years or later

than 2 years), type of exposure, time point of measuring the outcome as well as which outcome was measured (liking, preference or intake), which stimuli were used in the outcome measurement (basic sweet taste versus a sweet flavor; liquid, semi-solid or solid stimuli), and which method was used to assess the outcome (rating scale, liking, forced-choice test).

3. Results

3.1 Included papers and key study characteristics

Fourteen papers could contribute to our research aim. Twelve papers were longitudinal cohort studies and only two were controlled experimental studies. Table 1 shows the characteristics and findings of the 12 cohort studies, and Table 2 summarizes the characteristics and findings of the two controlled experimental studies. For the longitudinal observational studies, papers were organized into two main groups based on the age period of sweetness exposure. Eight papers investigated the effect of early exposure in infancy (0-2 years) and four papers investigated the effect of later exposure (>2 years) on sweetness liking or intake of sweet products. Subsequently, a distinction was made based on the time between exposure and measurement of the outcome variables. Thus, papers were considered to assess either the shorter-term effects (<1 year) or longer-term effects (≥1 year) of exposure on sweetness liking or intake of sweet products.

3.1.1 Short-term effects of early exposure to sweetness in infancy (0-2 years)

Only one paper focused on the short-term effects of early exposure to sweetness (Beauchamp & Moran 1982). In a sweetness taste test at the age of six months, the researchers found that infants who were regularly fed sweetened water within the first six months consumed higher

amounts of sucrose-sweetened water solutions compared to infants who did not have a sweet water feeding history. No difference was found for the consumption of plain water. Exposure to sweetened water was inferred from a seven-day recall filled out by the mothers when the infant was six months old. Although the exposure frequency to sweetened water varied between one and 20 times during the assessment period, mothers who have fed sweetened water during the seven days almost always reported having followed this procedure during the whole preceding six months. Thus, even though the exposure frequency to sweetened water varied between the children, all infants assigned to the sweet exposure group received sweetened water frequently within their first six months. Following that, the paper points towards a short-term effect of exposure to sweetened water during the first six months of life on sweetness liking among six-month-old infants.

3.1.2 Longer-term effects (≥ 1 year) of early exposure to sweetness in infancy (0-2 years)

Six papers measured the influence of early exposure to sweetness on sweetness liking or intake of sugary foods and drinks later in childhood. In these studies, children were classified into high(er) exposure or no exposure to sweetness by either their consumption of sweetened water (basic sweet taste: ≤ 6months, > 6 months, not exposed) (Beauchamp & Moran 1984; Pepino & Mennella 2005), routinely consumption of added sugar (yes or no) (Liem & Mennella 2002), low, medium and high consumption of commercial complementary foods containing high levels of added sugars (Foterek et al. 2016), exposure (yes or no) to a slightly sweet nutritional supplement (Okronipa et al. 2019a; Okronipa et al. 2019b) or exposure to five particular sweet foods and drinks during the first two years of life (having tried; yes or no) (Jackson et al. 2020). Whereas papers on sweetened water experience focused on exposure to a basic sweet taste, the other four papers focused on potential effects of exposure to more complex sweet flavor profiles

(Liem & Mennella 2002; Foterek et al. 2016; Okronipa et al. 2019a; Okronipa et al. 2019b; Jackson et al. 2020).

Different findings are reported in the above-mentioned papers regarding the longer-term effect of early exposure to sweetness in infancy. A positive relationship was found between exposure to sweetened water and longer-term liking for higher sweetness intensity in sucrose-sweetened water solutions in the papers where sweetness liking was measured through a basic sweet taste to which the child had been exposed during the exposure period (Pepino & Mennella 2005; Beauchamp & Moran 1984). However, when measuring sweetness liking not only through a basic sweet taste to which the child had already been exposed but also through a sweet fruit flavored drink, no relationship was found between being fed sweetened water and liking for the sweet fruit flavored drink at two years (Beauchamp & Moran 1984). Despite, prior exposure to the specific fruit flavored drink was associated with consuming more of the sweetened and unsweetened fruit flavored test solutions (Beauchamp & Moran 1984). Further, when looking at dietary patterns associated with sweetness exposure (e.g. adding sugar to the child's diet) a diverse picture seems to appear. On the one hand, when children were exposed to added sugars in their diet during the first 12 months of life, they were more likely to prefer apple juice with added sugar at the age of four to seven compared to children who were not routinely fed added sugar to the diet (Liem & Mennella 2002). In line with this finding, in infancy, higher consumption of commercial complementary foods which contain added sugars was correlated with a higher intake of added sugars at pre-school and primary school age (Fotorek et al. 2016). On the other hand, the other two papers that focused on early exposure to a sweet flavor found no relationship between early sweet taste exposure and later sweetness liking. In the study by Jackson and colleagues (2020), early exposure to commonly restricted foods such as cakes, candies and sweet drinks, was operationalized as having tried these foods at 14 months or two

years of age. Here, early child exposure did not predict the child's liking for the sweet food and drink items at the age of five years. Hence, the authors conclude that early exposure to sweetness may not be an important predictor of child liking when the children are five years of age. (Jackson et al. 2020). In the two papers of Okronipa et al. (2019a; 2019b), early exposure to a slightly sweet nutritional supplement was neither related to the child's liking for sweet foods and beverages (Okronipa et al. 2019b), nor to his/her sucrose preference at age four to six (Okronipa et al. 2019a). It needs to be acknowledged though that consumption of other sweet foods and beverages was not assessed in this study. Exposure to these could have overruled the effect of exposure to the slightly sweet nutritional supplement on which the researchers focused (Okronipa et al. 2019a; Okronipa et al. 2019b).

To summarize, when sweetness liking was measured for a similar flavor profile as the child was exposed to in early childhood (i.e. sweetened water), a positive relationship between exposure and liking at a later age was found. Studies focusing on more complex flavor profiles found different results. Two papers reported a positive relationship (Fotorek et al. 2016; Liem & Mennella 2002), whereas three papers did not find any association between early sweetness exposure and liking later in childhood (Okronipa et al. 2019a; Okronipa et al. 2019b; Jackson et al. 2020).

3.1.3 Short-term effects of exposure to sweetness during later childhood (4-12y)

Three papers that investigated the relationship between exposure to sweetness at age four to twelve and short-term effects (within one year after exposure) on sweetness liking or intake of sweet items found different results. Jackson et al. (2020) – discussed above – reported that a high intake frequency of sweet foods and drinks at age five predicted a high liking for these same sweet items (Jackson et al, 2020). In contrast to that, in a large European study, no

association was found between sweetness liking and the consumption frequency of sweet foods in 1696 children aged six to nine years from eight different European countries. Sweetness liking was measured using a forced-choice paired comparison test with two apple juices varying in sweetness concentration, so a test product with a sweet flavor profile. In this study, eight to nine year-old children preferred higher sweetness intensity levels than six to seven year-olds (Lanfer et al. 2012), suggesting that age itself could have a stronger impact on sweetness liking than short-term sweetness exposure. In line with these findings is the outcome of a paper by Divert et al. (2017), who studied 101 children aged seven to 12 years. The researchers used preference tests with five levels of sweetness for three different matrices each, covering basic sweet taste (sucrose in water) and two different sweet flavor profiles (strawberry syrup in water and semi-skimmed milk with cereals). Although there was a weak but significant positive association between sweet candy and snack consumption and sweetness liking, sweetness liking was not associated with sweet drink consumption, cereal, dairy, fruit or added sugar consumption (Divert et al. 2017). Besides the paper by Jackson et al. (2020) that also looked at early exposure and intake as discussed in the previous chapter, the two studies that particularly focused on short-term exposure at later age, concluded there is no clear association between frequency of exposure (Lanfer et al 2012) or sweet food consumption (Divert et al, 2017) and sweetness liking in children aged six to 12 years.

3.1.4 Longer-term effects of sweetness exposure during later childhood (4 – 12 years)

Two papers with comparable sample sizes investigated the relationship between sweetness exposure at age four or five and longer-term impacts on sweetness liking, preference or intake of sweet products when children were five to 15 years old (Fiorito et al. 2010; Vennerød et al. 2017). One study, using dietary recalls at six time points, showed that seven to 15 year-old girls

tended to have a higher consumption of sweet beverages when they consumed soda at the age of five, compared to girls who did not consume soda at the age of five. The early consumption of soda was also associated with a higher general sugar intake and a less healthy diet throughout childhood, up until the age of 15. The poorer diet was reflected in a lower intake of protein, fiber, vitamins and minerals as the diet of girls who were not classified as soda consumers at the age of five (Fiorito et al. 2010). The results of this longitudinal study suggest that early intake of soda may be a predictor of higher sweet beverage intake and added sugar intake in childhood and adolescence, and may relate to an overall poorer diet. Similar findings were reported by Vennerød et al. (2017) who found that exposure frequency to sweet foods and snacks at age four was associated with a higher sweetness preference in both liquid and solid foods (i.e. fruit flavored drinks and chocolate). This association was present at baseline (in the first year of the study when children were four years old) and became even stronger after one year. However, children who were more often exposed to fruit preferred lower sweetness in the drinks, but not in chocolate. In addition, a higher sensitivity to sweet taste was associated with lower sweetness preferences, suggesting that individual factors may play a role as well. In conclusion, these two studies point towards a positive relationship between exposure to sweet foods and beverages at age four or five and sweetness liking during later childhood and adolescence.

3.1.5 Experimental studies

Only two studies (Table 2) used controlled experimental designs in which exposure to sweetness was deliberately manipulated in a controlled manner to assess effects on sweetness liking (Sullivan & Birch 1990; Liem & de Graaf 2004). Both studies used multiple exposure days during the intervention period, which was operationalized as 15 exposures during nine

weeks (Sullivan & Birch 1990) or in a shorter time frame of eight exposures on eight consecutive days (Liem & de Graaf 2004). Interestingly, both interventions used two different sweetness carriers during the preference measurements to study generalizability effects. Besides the matrix that was used during the exposure period (i.e. liquid in the study of Liem & de Graaf (2004) and solid in the study of Sullivan & Birch (1990)), a semi-solid carrier (i.e. yoghurt and ricotta cheese) was included. When children were repeatedly exposed to an initially novel food (tofu) with either a sweet, salty or plain flavor profile, children showed an increased liking for the tofu they were exposed to, but this effect did not transfer to the other matrix (ricotta). Thus, the children who were exposed to the sweet tofu increased their liking for the sweet tofu but neither for the salty and plain tofu nor for the sweetened ricotta cheese (Sullivan & Birch 1990). This finding rather supports the positive effect of repeated exposure to a novel, unfamiliar food on its acceptance instead of delivering clear evidence for an effect of sweetness exposure on sweetness liking in general. In contrast to that, Liem & de Graaf (2004) used a familiar drink (orangeade) in the exposure period and found that a relatively short exposure period of eight exposures increased children's liking for the same high sweetness concentration (0.42M sucrose) as they were exposed to in the intervention period. The researchers reported a tendency ($p=0.09$) that this effect generalized to sweet fruit-flavored yoghurt with the same sucrose concentration (0.42M). Next to the sweetness exposure group, another group of children was exposed to sour lemonades. However, different to the sweet exposure group, the children in the sour exposure group did not change their sour preferences after eight exposures to sour-tasting orangeade. This indicates that exposure effects in children may differ for various taste modalities.

Concluding, both controlled experiments suggest that repeated exposure to a sweet product may increase preference for that particular sweet product. Yet, this effect does not seem to be

consistent for all taste modalities. Furthermore, one study found some evidence for generalization of increased sweetness preference to other food products, whereas the other did not.

Discussion

This review aimed to provide an overview of the current evidence regarding the effect of sweet taste exposure on sweetness liking and intake of sweet foods in children. Fourteen studies were included, 12 of them were observational studies and two used a controlled experimental design. We organized studies into two groups based on early exposure in infancy (0 – 2 years) or later exposure (> 2 years), and subsequently, on shorter-term effects (< 1 year after exposure) or longer-term effects (≥ 1 year after exposure) on sweetness liking or intake of sweet foods and beverages.

The findings provide some evidence for short-term effects of early exposure in infancy on subsequent sweetness liking and intake of sweet foods. However, these effects appeared to be dependent on a similarity in flavour profiles between the test products and what the infant had experienced during the exposure period. To illustrate, exposure to sweetened water within the first six months resulted in a higher liking for sucrose-sweetened water at the age of 6 months (Beauchamp & Moran, 1982). Also on the longer term, a positive relationship was found between exposure during infancy and sweetness liking and intake later in childhood (2 – 10 y), when sweetness liking was measured for similar flavour profiles as the child was exposed to during infancy. Exposure to sweetened water within the first six months resulted in a higher liking for sucrose-sweetened water at a later age (Beauchamp & Moran, 1984; Pepino & Mennella, 2005). In addition, prior exposure to a specific fruit flavoured drink was associated

with consuming more of this plain or sweetened fruit flavoured drink during preference tests, but not of sucrose-sweetened water (Beauchamp & Moran, 1984). These findings imply that the effects of early exposure to sweetness on subsequent sweetness liking or intake may be due to increased familiarity through repeated exposure rather than an increase in sweetness liking. Regarding the longer-term (more than one year after exposure) effects of sweetness exposure during infancy on sweetness liking for, and intake of, foods and beverages with more complex flavour profiles, the findings were inconsistent. Two papers reported a positive relationship (Fotorek et al., 2016; Liem & Mennella, 2002), whereas three papers did not find any association (Okronipa et al., 2019a + 2019b; Jackson et al., 2020). An explanation for these ambiguous results may be found in differences between study designs, study populations, methodology used, or other factors that may have played a role besides exposure. This will be discussed in more detail later on in this section.

Findings were also inconclusive when looking at the exposure to sweetness beyond infancy (i.e. four years of age and onwards) and how that influences sweetness liking and intake frequency of sweet foods and drinks in the short-term or during later childhood and early adolescence. On the one hand, dietary patterns at an early age that were high in sugar intake (e.g. consumption of sugar-sweetened beverages or sweet foods and snacks), were found to be related to a high liking for these same sweet foods and beverages and a subsequently higher sugar intake throughout childhood (Vennerød et al., 2017; Fiorito et al., 2010). Yet, other papers reported no associations between frequent dietary exposure to sweetness and sweetness liking or (frequency of) consumption of sweet foods and beverages later in childhood (Lanfer et al., 2012; Divert et al., 2017). What hampers the interpretation of these findings, is that these were all longitudinal observational studies, with a correlational design. This makes it difficult to make inferences about cause and effect. For example, a longitudinal study found a relationship

between consumption of sweetened carbonated drinks (soda) at age five and a higher consumption of sweet beverages, a higher general sugar intake and a less healthy diet throughout childhood up to 15 years of age. This suggests that early intake of soda may be a predictor of higher sweet beverage intake and added sugar intake in childhood and early adolescence. However, it may also be the case that consumption of soda at age five is not a predictor but just a reflection of an overall poorer diet at a young age, which persists in later childhood. Controlled experimental studies are better suited to study cause-effect relationships, but we found only two of them (Sullivan & Birch, 1990; Liem & de Graaf, 2004). Interestingly, these studies do provide some evidence that repeated exposure to products with a higher sweetness intensity may increase sweetness liking and preference, at least in the short-term immediately after the intervention. Whether these effects persist in the longer term, is a question that remains to be answered.

The studies identified for this review differed substantially in study design, population, how sweetness exposure was operationalized and in the methods to assess sweetness liking or intake of sweet foods and beverages of the children. This observation is similar to a recent review on the topic among the whole age range, from infants, children, to adolescents and adults (Appleton et al. 2018). As this heterogeneity made the comparison between studies difficult, it is useful to point out some of these differences in more detail.

Firstly, some studies had a crude assessment of sweetness exposure and classification into the groups that were compared. For example, one paper on early exposure to a set of commonly restricted foods and beverages (e.g. sweet drinks, candies or cakes) grouped children into having tried the food/drink vs. not having tried them at an early age (Jackson et al.,2020). This method partly ignores the relevance of exposure frequency to sweetness or the sweetness intensity level. In addition, some papers focused on exposure or no exposure to commercial

complementary foods, containing high levels of added sugar (Fotorek et al. 2016), or to a slightly sweet nutritional supplement yes or no (Okronipa et al. 2019a + b). Through this approach, the researchers did not control for other sweet foods and beverages the child may have consumed. In these cases, it may well be that dietary exposure to other sweet-tasting foods and drinks has overruled the effect of exposure to the foods or supplements which the researchers focused on.

Secondly, part of the studies was undertaken in infants and young children. In this age group, a strong innate liking to sweetness exists (Nehring et al., 2015) to which parents may react to by intervening in their child's consumption of sweet foods and drinks. Therefore, differences in dietary intakes are greatly influenced by parents and may rather reflect parents' food offerings and parental practices than children's preferences for specific sensory attributes. To illustrate, parental practices such as using food as a reward or parental attitudes towards their child's diet in terms of health, sugar intake and taste importance were all related to the child's exposure to sweet foods, snacks, and fruits (Vennerod, 2017). Furthermore, mothers' liking for sweet foods and drinks was an indicator of the child's liking for the same products (Jackson et al. 2020). This indicates that parents' preferences for sweet foods have a big impact on their child's sweetness preference. In addition, psychological factors may play a role as well. Children facing high parental restrictions regarding sugar intake showed an increased sweetness preference (Venditti et al. 2020). When sweet foods and beverages are restricted, sweetness preferences could enhance as a result of "craving the forbidden fruit" (Liem 2004; Jansen et al, 2007). In addition, using sweet foods as rewards may have similar effects on sweetness liking as restrictions. This is indicated by Vennerød et al. (2017) who found a relationship between higher parental use of food rewards and preference for the sweetest chocolates and drinks in a paired comparison procedure.

Next to methodological aspects and parental influences, individual child characteristics most likely influence sweetness liking as well. Age itself was found to play a role in sweetness preference with increasing preferences during childhood (Lanfer et al. 2012; Vennerød et al. 2017). In these studies, five year-olds showed higher sweetness liking than four year-olds (Vennerød et al. 2017) and eight to nine year-olds higher sweetness liking than six to seven year olds (Lanfer et al. 2012). Following Ventura and Mennella (2011), the preferred sweetness intensity seems to decrease again during adolescence. Because the papers included in this literature review focused on different age groups, it cannot be ruled out that participants' age influenced the results.

Similar to the U-shaped curve of sweetness preference from a young age to adulthood, the detection-threshold for sweetness seems to follow the same pattern. While the threshold tends to increase in childhood (Vennerød et al. 2017), it decreases in adolescence and adulthood (Petty et al. 2020). For example, age was related to sensitivity for sweetness with decreased sweetness sensitivity from age four to six (Vennerød et al. 2017). This could result in a higher threshold for sweetness detection so that six year-old children need higher sweetness intensities to experience the same perceived sweetness as four year-old children. It has been argued recently, that age-related changes in sweetness liking rather result from developmental processes from childhood to adulthood which lead to changes in sucrose detection thresholds, with adults preferring lower sucrose concentrations than children (Petty et al. 2020). Interestingly, the researchers did not find a strong relationship between detection threshold and sweetness preference and, therefore, concluded that age-related differences in sweet taste sensitivity cannot be the sole reason why children have higher sweetness preferences than adults (Petty et al. 2020).

Another individual factor that my impact sweetness liking is hunger status during the sweetness liking assessments. In a meta-analysis, Venditti et al. (2020) reported that in multiple studies, participants' sweetness liking was increased when they were in a hungry state compared to being in a fed state. Although this analysis was not only focused on children, the outcomes of the included papers in this literature review could have been influenced by children being in a fasted versus fed state.

The fact that some papers found an increase in sweetness liking when the assessment was done with the same food or beverage the child has been exposed to (Sullivan & Birch 1990), points towards increased liking after repeated exposure. Especially for novel, initially disliked foods such as vegetables, repeated exposure is an effective method to increase acceptance for these foods in children (Nekitsing et al. 2018; Zeinstra et al. 2018; De Wild et al. 2013). However, sweet taste may differ from other taste modalities, as sweet taste is already liked at birth and therefore liking does not need to be learned. Vennerød et al. 2017 reported that the preference for bitterness and sourness were stable at age four to six, whereas the one for sweetness increased over that time.

One aspect often ignored in the debate about the effect of sweetness exposure on sweetness liking and intake of sweet foods and drinks is that consumption of sweet foods and beverages can also lead to a decreased desire to consume sweet products, due to sensory-specific satiety (SSS). A robust body of evidence shows that exposure to a particular sensory attribute (e.g., sweetness) may lead to a reduction in liking and choice of foods and beverages with that same attribute, relative to others (Rolls, 1981; Rogers et al. 2020). Although the phenomenon of SSS has received limited attention in children so far, some studies indicated SSS may play a role in children as well. In a study by Ogden and colleagues (2013), parents received chocolates to give to their children either throughout a weekend (study one) or two weeks (study two), either

in a restricted or unrestricted condition. Children who were unrestricted and allowed to eat as much of the chocolates they wanted, showed a lower desire for chocolate than the children who were restricted regarding their chocolate consumption (Ogden et al. 2013).

To our knowledge, this literature review is the first comprehensive review on the influence of sweet taste exposure on subsequent sweet taste liking and intake of sweet foods which focused on children. The conclusions of this review are limited due to the small number of studies and their inconclusive findings. Children's young age presents some limitations in this area of research. Often, one has to rely on parent-reported data on both children's exposure to sweetness as well as on their preferences and intake of sweet foods and beverages. Young children have limited capacity to perform complex preference tests or to express themselves in a sophisticated manner about their likes and dislikes. Also, children's age varied a lot between the studies, with new-borns and infants exclusively being exposed to liquid foods in some studies, whereas other studies used solid foods to measure exposure.

This review shows a clear need for future experimental controlled studies, as only two were identified in our overview. These controlled studies should include longer follow-up periods to investigate the longer-term effects of the interventions. Furthermore, longer-term cohort studies that follow groups of children who naturally vary in the sweetness of their diet over several years would help find answers. Finally, studies are needed to disentangle the effects of exposure to sweet taste from dietary sources with low amounts of sugar (i.e. containing low calorie sweeteners) versus high amounts of free sugars. This poses a sensitive topic in children, but resolution of this issue is important for ensuring the most efficacious, evidence-based public health advice, with important implications for parents and caretakers and for the development of commercial food products reduced in sugar and targeted at children.

To conclude, only limited evidence exists regarding the relationship between sweetness exposure and sweetness liking or intake of sweet products. The small body of findings is even weakened through heterogeneous results, making it difficult to draw general conclusions. So far, the available evidence suggests an increased sweetness liking after exposure to sweet taste for similar flavour profiles, both when looking at shorter-term and longer-term effects. As for generalizability to other sweet-tasting foods and beverages, and the relationship with intake and consumption patterns, the inconsistent findings do not warrant clear conclusions. Further research and more controlled experimental studies are needed to understand how early exposure to sweetness shapes food preferences, liking and food intake in the long term.

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TABLE 1
Longitudinal cohort studies investigating the impact of sweet taste exposure on subsequent assessments of preference for or acceptance of sweet taste[1]

Study	Study population, age at O	E intervention	E intervention assessment	Groups compared	O	O assessment	Main findings	Interpretation	Considerations / Other
EARLY EXPOSURE (0-2 years)									
Beauchamp & Moran (1982)	140 infants (6 months)	Consumption of sweetened water (with sugar, Karo syrup or honey) during infancy (0 - 6 months)	Parent-completed 7-days dietary record of everything the infant consumed, including sweetened water, at age 6 months	Regular vs. never fed sweetened water within first 6 months	Sweetness liking / acceptance (basic sweet taste)	Intake (consumption volume) of plain water vs. sucrose-sweetened water solutions differing in sweetness (.2, and .6 M)	Infants who were regularly fed sweetened water within the first 6 months of age ingested significantly more of the .2 and .6 M sucrose-sweetened solutions, but not more plain water, compared to infants who were not routinely fed sweetened water Dietary records indicated little difference in the patterns of feeding (i.e. exposure to other sweet tasting foods) between infants fed sweetened water and infants not fed sweetened water	Previous feeding experiences with sweetened water increase the responsiveness (consumption volume) to sucrose solutions at 6 months of age	Infants were also tested as newborns. Compared to responses at birth, intake of sucrose-sweetened solutions relative to water declined in 6 months old infants not fed sweetened water. At birth, sucrose solutions is not a novel sweet stimulus because taste experience is limited and there is little with which to compare the solutions However, for older infants with little experience of sweet water feeding, a sucrose solution is novel and hence 'familiarity' may have played a role here
Beauchamp & Moran (1984)	63 children, aged 2 years (sub-sample	Consumption of sweetened water (with sugar, Karo syrup or honey)	Parents completed questionnaire to assess whether, how frequently, and until	3 groups: Never fed sweetened water vs. fed sweetened water	Sweetness liking / acceptance	Intake (consumption volume) of plain water vs. sucrose-	The two groups fed sweetened water consumed more sucrose solution	Previous feeding experiences with sweetened water increase the	More sweetened Kool-Aid drink was consumed

	of 1982-paper)	during infancy/ early childhood	what age the infant had been fed sweetened water (water with table sugar, Karo or honey)	≤ 6 months vs. fed sweetened water > 6 months	(basic sweet taste + sweet flavor)	sweetened water solutions differing in sweetness (.2, and .6 M) (see procedure Beauchamp and Moran (1982)) + Intake of fruit-flavored drink (Kool-Aid cherry flavor) in two forms: unsweetened +.6M	during taste tests than children who were never fed sweetened water No significant correlation between number of months being fed sugar water and consumption volumes of taste solutions Prior experience with sweetened water was not related to consumption of sweetened or plain Kool-Aid Children who had never experienced Kool-Aid consumed less of it regardless of whether it was sweetened with sucrose or not	responsiveness (consumption volume) to sucrose solutions at 2 years of age, but these experiences do not transfer to another medium: a (sweetened) fruit-flavored drink Effects of dietary exposure on sucrose acceptability may be specific to the medium in which sucrose was dissolved	than plain Kool-Aid There was a significant correlation between sucrose acceptability determined at 6 months and at 2 years of age, but no significant relationship among consumption at birth and at 2 years of age
Liem & Mennella (2002)	83 children aged 4 – 7 y	Consumption of added sugar to child's diet during infancy (0 – 12 months)	Parent-completed retrospective recall of feeding habits + child's favorite cereals and candies	Children who were fed milk-based formula vs. children who were fed hydrolysate formula (sour taste), separated by age (4 – 5 y	Preference for sweetness concentrations (sweet flavor)	Forced-choice paired comparison test of pairs of apple juices with different sugar concentrations (water-diluted stock .34 M juice to .16 and .22 M, or by	No differences in preferred sweetness concentrations between age groups and formula groups. Children who had routinely sugar added to their diets during	Routinely adding sugar to children's diet during infancy (0 – 12 months) is associated with higher preferences for	Preferences for sourness: Children aged 4 – 5 y, who were fed hydrolysate formula during infancy preferred sour juices (citric acid added; .007, .012, .022, .039, .0.07 M)

				vs. 6 – 7 y); 4 groups		adding sugar to .47, .66, and .93 M)	infancy, were significantly more likely to prefer the apple juices with added sugar	sweetness later in childhood	more than 6 – 7 year old children fed similar hydrolysate formulas. No such age difference for children fed milk-based formulas in sourness preference
Pepino & Mennella (2005)	128 children aged 6 – 10 y	Consumption of sucrose-sweetened water during infancy	Parent-completed questionnaire for practice of feeding children sweetened water during infancy	Regular vs. never or rarely (<10 times) been fed sweetened water	Preference for sweetness concentrations (basic sweet taste)	Forced-choice, paired comparison tracking test of pairs of sucrose-sweetened water solutions differing in sweetness (.09, .18, .35, .70, and 1.05 M)	Children who were routinely fed sugar water during infancy preferred significantly higher levels of sucrose (0.66 ± 0.07 M) compared to those never or rarely exposed (0.48 ± 0.04 M)	Exposure to sweetened water during infancy is associated with higher preferences for sweetness later in childhood	O assessment also done by the mothers: Children preferred significantly higher sweetness concentrations than mothers
Foterek et al. (2016)	288 children measured twice; at 3 – 4 y, and 6 – 7 y	Habitual consumption of commercial complementary foods (CCF), containing high levels of added sugar, in infancy (0.5 – 0.75 y)	Parent-completed 3-days weighed dietary records (all foods and beverages the child consumed on 3 consecutive days) at 3 timepoints; 0.5 – 0.75 y (infancy), 3 – 4 y (preschool) and 6 – 7 y (primary school)	Low, medium, and high consumption of CCF during infancy	Dietary sugar intake	daily absolute (g/d) and relative added sugar intakes (En%/d) as well as energy intakes (kJ/d) were derived from the mean of the 3 days dietary records	In infancy, a higher intake of CCF was associated with a higher total added sugar intake A higher intake of CCF during infancy was related to higher added sugar intake in both pre-school and primary-school age children	Higher exposure to added sugar through commercial complementary foods during infancy may predispose to higher added sugar intake in later childhood	It may not be the high intake of CCF, but a less favorable infant diet with other sweetened products apart from complementary foods, explaining the found associations
Okronipa et al. (2019a)	624 Ghanaian children aged 4 – 6 y	Early exposure to a slightly sweet nutritional supplement (during pregnancy and	Interview with parents (when the child was between 0 – 18 months of age) on feeding practices of infants and young children,	Early exposure to a slightly sweet tasting nutritional supplement (n=323) vs. non-flavored	Preference for sweetness concentrations	Forced-choice, paired comparison tracking test of 5 sucrose-sweetened water solutions differing in	No difference in preferred sucrose levels between children being offered slightly sweet vs. non-flavored nutritional	No long-term impact of early and prolonged exposure to a slightly sweet supplement on	Controlled experiment with regard to the sweet vs. non-flavored supplements, but exposure to other

		after birth during breastfeeding) and during infancy by receiving the sweet supplement from 6 – 18 months	including a questionnaire on the frequency of consumption of specific foods / beverages by the child in the 7 d preceding the interview Questionnaire had a total of 32 food and beverage items belonging to food categories (e.g. fruits, vegetables, sugary foods). There were 6 sugary items: i.e. fruit juice, sugary drinks, chocolate (drink), sweets, candies and cakes, sweet pastries	nutritional supplements (n-301)	(basic sweet taste)	sweetness (.09, .18, .35, .70, and 1.05 M)	supplements during early life Daily provision of a slightly sweet supplement to mothers during pregnancy and 6 months postpartum and to infants from age 6 – 18 months does not impact sweet taste preference at age 4 - 6	sweet taste preference of children later in childhood	sweet tasting foods / beverages during infancy (6 – 18 months) was not controlled for, which may have overruled the effect of the supplement flavor
Okronipa et al. (2019b)	*See Okronipa et al. 2019a*	*See Okronipa et al. 2019a*	Interview with parents (when child was 4 – 6 y) on frequency of consumption of different food items in the 7 d preceding the interview. Food items were grouped into: SSB; sweet and savory foods eaten as snacks or with meals; peanut-containing foods; foods containing eggs, fish, or meat; fruits and vegetables	*See Okronipa et al. 2019a*	Sweetness preference (sweet flavor)	Variant of a ranking order procedure using photos of the same 30 food and beverage items that were included in the checklist for the 2nd part of the parent questionnaire described under 'E intervention assessment' First, children were asked to choose as many items as they would like to have "right now" out of the 30 items (15 of which were sweet).	No difference in preferences for sweet foods and beverages between children being offered slightly sweet vs. non-flavored nutritional supplements during early life No association between consumption frequency of sweet foods and beverages at age 4 – 7 and early life exposure to a	No long-term impact of early and prolonged exposure to a slightly sweet supplement on children's sweet taste preference or intake of sweet foods/drinks	

			2nd part of the questionnaire assessed parent-reported food preferences of the child using a checklist of 30 specific foods and beverages commonly consumed by children 4 - 6 y in Ghana, including: 5 sweet, low nutrient-dense beverages; 5 fruits; 5 sweet low fat, low nutrient-dense foods; 5 sweet, high fat, low nutrient-dense foods; 5 vegetables; and 5 savory, high fat, low nutrient-dense items. For each food and beverage item, parents were asked to indicate the child's liking on a 5-point scale (like very much, like a little, dislike, never offered or tried, don't know)			Second, children were asked to choose their favorite 5 food and beverage items out of the items they selected in the first level	slightly sweet tasting nutritional supplement		
Jackson et al. (2020)	211 mothers of 5-year old children	Early exposure (having tried) at 14 months & 2 years	Parents completed a 5-point liking scale with additional option (never tried) for 8 food/drink items of which 5 were sweet	Early exposure (having tried the food/ drink) versus not tried (no early exposure) at 14 months + at 2 years	Sweetness liking for often restricted foods/drinks (sweet flavor)	Parent-reported child-liking for food/drink items: likes a lot (score 1) versus other (score 2-5)	Child early exposure did not predict child liking for the restricted items Child high intake frequency predicted higher odds of	Early exposure may not be an important predictor of child liking for restricted foods and drinks when children are 5 years	Sweet biscuits and cakes were consumed most frequently: 48% consumed these items three or more times a week

						Intake frequency of the selected restricted foods	child high liking for the sweet foods and drinks (i.e. soft drink, fruit drink, lollipops (sweets), cakes and sweet biscuits, but not for any of the savory foods.	A high child intake frequency of sweet foods and drinks at 5 years predicts a high child liking for the same sweet restricted items.	Proportion of children who had tried the restricted foods and drinks progressively increased from 14 months to 5 years old. Mothers' own high liking for both sweet and savory foods and drinks predicted child high liking for the same items at 5 years old
LATER EXPOSURE (4-12 years)									
Fiorito et al. (2010)	166 girls measured at age 5, 7, 9, 11, 13, and 15 y	Consumption of sweetened carbonated beverages (soda) at age 5	Parent-completed 3 days 24-hour dietary recalls (all foods and drinks consumed) at ages 5, 7, and 9. At ages 11, 13, and 15 y the girls completed the 24-hr recalls themselves, with assistance from the parents if needed Beverage output files used to calculate average of 3 days' beverage consumption into five categories: milk, fruit juice, fruit	Soda consumers vs. non-soda consumers at age 5 (non-soda consumers = no reported intake of soda on one of the 3 days from the dietary recall)	Differences at each time of assessment and changes from age 5 to 15 years in mean beverage intake	Percentage of energy intake consumed from all beverages, and the overall % of energy obtained from sweetened beverages, for all measurements	Girls consuming soda at the age of 5, continued to have a higher intake of soda from age 7 to 15 Soda consumption at age 5 was associated with higher added sugar consumption and less healthy dietary patterns (lower % of energy coming from protein, fiber, vitamins and minerals) from age 5 to 15	Early intake of soda may be a predictor of higher sweet beverage intake and added sugar intake in childhood and adolescence	

			drinks, sodas, tea/coffee						
Lanfer et al. (2012)	1696 children aged 6 - 9 y (IDEFICS European cohort)	Consumption of sweet foods	Parent-completed questionnaire (CEHQ-FFQ) about consumption frequency of the child of 43 food items (including sweet foods / beverages) in a typical week during the preceding 4 weeks	Association between sweet food consumption and sweetness liking	Preference for sweetness concentrations (sweet flavor)	Forced-choice paired comparison test of 2 apple juices with different sugar concentrations (0.53% vs. 3.11% added sugar)	No significant association between frequency of consumption of sweet foods and sweetness preference	No relation between frequency of exposure to sweet taste and higher intensity sweetness preference	Consumption frequency of fatty foods and fat preferences also measured Higher weight status (overweight / obesity) was positively associated with higher fat and sweet preferences
Divert et al. (2017)	101 children aged 7-12	Sweet food and drink consumption	Children completed a food frequency questionnaire (with help of parents) covering the consumption of 40 sweet foods (caloric sweetened foods) and 12 sweet drinks (eight caloric and four non-caloric sweetened drinks)	Association between sweet food consumption and sweetness liking	Sweetness preference (basic sweet taste + sweet flavor)	Sweetness preference test, using five levels of sweetness intensity for three sets of food products (sugar in water, strawberry syrup with water and cornflakes in milk). Sucrose was added to: water, strawberry syrup with water, and semi skimmed milk in which cereals were added.	A weak but significant positive association between candy and snack consumption and sweetness liking. Sweetness liking was not associated with sweet drink consumption, cereal/ dairy/ fruit product consumption or added sugar consumption	No clear association between sweet food consumption and sweetness liking at age 7-12 years except for candy and snack consumption which was weakly associated with sweetness liking	Liking for sweetness depended on product matrix: For sugared water, 32% of the participants had a positive preference score (higher liking scores to the sweeter levels) for the sugared water and 49% a negative score (higher liking scores to the less sweet levels) For the strawberry syrup water, 39% had a positive score and preferred the sweeter levels and 38% a negative score. the less sweet levels

						Percentage of added sucrose: Water matrix =3.1%, 6.2%, 12%, 24%, 35.9% Syrup matrix =0%, 1.3%, 2.5%, 8.7%, 14.5% Milk matrix = 0%, 2.5%, 9.4%,17.7%, 31.3%			For the sweetened milk with cornflakes, 57% preferred the sweeter levels had a positive score and 21% the less sweet level
Vennerød et al. (2017)	135 children measured twice: year 1 (aged 4 y), and year 2 (aged 5 y)	Frequency of exposure to sweet foods and snacks, and fruits in the child's diet	Parent-completed questionnaire about the child's exposure to 35 food items containing a high amount of sweetness or bitterness Parent-completed 5 point Likert scales (1 = not agree at all; 5 = completely agree) on attitudes and behaviors towards their child's diet: parental health attitude, parental sugar attitude, parental use of food rewards, and parental taste attitude	Structural equation model run twice to compare data from the 2 years of measuring (age effects)	Sweet taste sensitivity (basic taste) Preference for sweetness concentrations (sweet flavor)	Discrimination task in a paired comparison procedure, successively opposing plain water to one of four sucrose-sweetened water solutions (.94, 1.56, 2,59, and 4.32 g/l) Ranking by elimination preference test with 3 fruit-flavored drinks different in level of added sugar: 4% vs. 12% vs. 18%, and 3 dark chocolates varying in cocoa content: 45%, 55%, and 65%, corresponding to different	No age effects on preference; subsequently only findings of Year 2 data reported Children with a higher sweet taste sensitivity significantly preferred the less sweet drinks A more frequent exposure to sweet foods and snacks was associated with a higher sweetness preference in both drinks and chocolate Children more often exposed to fruit preferred lower sweetness in drinks,	More frequent exposure to sweet foods and snacks in the child's diet is related to higher preferences for sweetness Parental attitudes towards their child's diet in terms of health, sugar intake, taste importance and use of food rewards is related to the child's exposure to sweet foods and snacks, and fruit Higher sensitivity to sweet taste in children is	Bitter taste sensitivity and preference for bitterness concentrations also measured

						sweetness and bitterness levels	but no effect for the chocolate. Higher parental use of food rewards was related to a preference for the sweetest chocolates and drinks Higher parental concern regarding health, sugar intake and/or taste importance for their child's food, exposed their children to less sweet foods and snacks	associated with lower sweetness preferences	

[1]References were ordered by early exposure (0 – 2 years) and later exposure (4 - 10) years, followed by recency of the paper (oldest first).

Abbreviations: E = exposure, O = outcome

TABLE 2

Controlled experimental studies investigating the effect of sweet taste exposure on subsequent assessment of preference for or acceptance of sweet taste

Study	Study population	Procedure	E duration	Groups compared	O	O assessment	Main findings	Interpretation	Considerations / Other
Sullivan & Birch (1990)	39 children aged 44 – 71 months (mean age 55 months; preschoolers)	Baseline preference ranking of 6 novel/unfamiliar test foods: Plain, salted, sweetened tofu, and ricotta cheese Salted tofu (2 g NaCl/100 g tofu) Sweetened tofu (14 g sucrose/100 g tofu) Salted ricotta cheese (1.6 g NaCl/100 g ricotta cheese) Sweetened ricotta cheese (12 g sucrose/100 g ricotta cheese) Post-assessment 1 preference ranking of 6 test foods after 8th exposure Post-assessment 2 preference ranking of 6 test foods after 15th exposure	15 exposures (tasting) to either plain, salted or sweetened tofu over 9 week period	Children randomly assigned to plain, salted, or sweetened tofu group	Flavor preference	Preference ranking test of 6 test foods: children tasted each food and rated it on a 3-point scale; like, neutral, dislike. Within each category (like, neutral, dislike) products were then ranked from most to least liked	With repeated exposure, the preference for the initially novel food increases, regardless of whether it was plain, sweetened, or salted tofu No effect on the preference for the other, unexposed flavored food (ricotta cheese)	Exposure in preschoolers impacts on preferences for same sweetened food, but not for other sweet foods	No sole focus on sweetness or differences in sweetness intensity. This study demonstrates the effect of repeated exposure to unfamiliar foods with acceptance of the flavor increasing with exposure. No generalization to other foods

Liem & de Graaf (2004)	59 children aged 9 – 10 y	Preference was measured using a rank-ordering procedure at baseline and after the intervention, for a series of 7 sweet-sour orangeades, and 7 lemon-flavored sweet yoghurts Seven orangeades with similar concentrations of added sucrose (0.42 M), and different concentrations of added citric acid (0.0, .009, .013, .020, .029, .043 and .065 M) in 23 g concentrated orangeade and water for a total volume of 1.0 L Seven lemon-flavored yoghurts with similar concentrations of added sucrose (0.42 M) and different concentrations of added citric acid (0.0, .027, .038, .056, .081, .12, and .17 M)	8 exposures (≤ 200 ml) over 8 consecutive days to either orangeade (0.42 M sucrose) with no added citric acid, an orangeade (0.42 M sucrose) with 0.02 M citric acid added, or to no orangeade at all (control) The 'sweet' and 'sour' orangeade were equally liked at baseline	Children randomly assigned to Sweet, Sour or no orangeade group	Sweetness preference (flavor)	Rank-ordering procedure for a series of 7 sweet-sour orangeades and a series of 7 lemon-flavored sweet yoghurts	Children in the control and in the Sour group showed significant agreement in their most preferred orangeade and yoghurt at baseline and after the intervention. Children in the Sweet group increased their preference for the sweet orangeade (0.42 M sucrose and no added citric acid, $p<0.05$) and tended to have increased preferences for sweet yoghurt (0.42 M sucrose and no added citric acid, $p=0.09$)	Exposure to orangeade with a high sucrose concentration during childhood increases children's preference for this orangeade. This increase for a high concentration of sucrose was specific for the exposed high concentration of sucrose and seems not to be specific for the food	No evidence whether changed preferences in sweet taste are stable over time, and whether changed preferences are related to a change in intake (consumption frequency/volume) of sugar rich foods and beverages

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