

Understanding the Origin of Flavor Preferences

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Introduction

Food traditions mirror a people's beliefs and values and are among the last characteristic of a culture that is lost during the immigration of an individual or group into a new culture (Rozin, 1996). However, the origins of preferences and aversions for flavors and food in humans have elicited much speculation but, until recently, remarkably little experimental investigation (Ganchrow and Mennella, 2003). We now know that initial experiences with flavors occur prior to birth when the flavor of amniotic fluid changes as a function of the mothers' dietary choices (Mennella *et al.*, 1995). Some of these same flavors continue to be experienced in mother's milk (Mennella and Beauchamp, 1991). Because early flavor experiences have been shown to enhance acceptance and enjoyment of foods during weaning and childhood (Mennella *et al.*, 2001), culturally determined flavor preferences, one of the most enduring characteristic of an ethnic group, can be understood in the context of early flavor exposure.

The major factor that has inhibited even greater progress in understanding the origin of flavor preference is the absence of a robust paradigm to investigate the role of infant experience. Practically, it is difficult experimentally to vary the flavor experiences of infants and children over long time periods and so few studies investigating consequences of major differences in feeding experience have been conducted (Mennella *et al.*, 2001). What is needed is a naturally occurring flavor variation that can be exploited to investigate the effects on subsequent acceptance.

During the past decade, we have identified a convenient and powerful model system to study the origin of flavor preferences—infants' acceptance of formulas containing protein hydrolysates, the feeding regimen of choice for formula-fed infants who cannot tolerate cows' milk and other intact proteins (American Academy of Pediatrics, Committee on Nutrition, 1989). It is perhaps one of the most striking examples of a developmental change in chemical sensory perception. Although this type of formulas is extremely unpalatable to older children and adults because of its offensive flavor, infants 4 months of age or younger accept it without difficulty (Mennella and Beauchamp, 1991, 1996). However, if infants receive exposure by the third month of life, they continue to accept these formulas for a considerable period of time thereafter (Mennella *et al.*, 2003). From these data, we hypothesized that there is an early sensitive period during which the hedonic value of this formula—and likely the flavors of other foods and beverages—is established.

The overall goal of the present study was to explore the specificity of the flavor experience during this sensitive period. Although all brands of protein hydrolysate formula share common flavor attributes and are judged unpleasant by adults, they differ in their flavor profiles. Here we exploit the inherent flavor variation of different brands of formulas to determine whether experience with one brand of protein hydrolysate formula influences acceptance of another brand that differs in flavor. In other words, is the acceptance pattern that develops specific to the flavor profile experienced? Or does the infant, regardless of the brand of formula currently being fed, prefer the one that tastes sweeter or the one that tastes less bitter?

To this aim, we studied infants' acceptance of two commercial brands of hydrolysate formulas widely used in the Philadelphia area of the United States: Alimentum™ and Nutramigen™.

Materials and methods

Subjects

Three groups of healthy infants, whose ages ranged from 5 to 11 months, were formed on the basis of the type of formula they were being fed. Group 1 infants ($n = 20$) were being fed Nutramigen, Group 2 ($n = 16$) were being fed Alimentum, whereas Group 3 ($n = 13$) were being fed a milk-based formula and had never experienced hydrolysate formulas. As expected, those who were fed hydrolysate formulas (Groups 1 and 2) were often fed a milk- or soy-based formula during the first months (1.9 ± 0.2) of life and then, usually following their pediatrician's recommendation, switched to hydrolysate. However, none of the Group 1 infants were ever fed Alimentum and none of the Group 2 infants were fed Nutramigen. All testing procedures were approved by the Office of Regulatory Affairs at the University of Pennsylvania and informed consent was obtained from mothers prior to testing.

Test stimuli

Prior to the start of the study, we had a trained sensory panel of seven adults (three women, four men) evaluate the sweetness, sourness, bitterness, saltiness and unpleasantness of Nutramigen and Alimentum. Evaluation was done with nostrils pinched closed with a nose clip. This revealed that these two brands differed in their characteristic flavor profile such that Alimentum was judged to taste significantly sweeter [paired $t(6) = 4.55$, $P = 0.001$] and less sour [paired $t(6) = 3.29$, $P = 0.01$] and tended to be judged less bitter [paired $t(6) = 1.93$, $P = 0.05$] than Nutramigen, while both formulas retained the distinct, unpleasant casein-like flavor, possibly due to the volatiles since this was evident when the nostrils were not pinched closed.

Testing procedures

The infants' responses were monitored during an entire feed under naturalistic conditions in which infants determined the pacing and duration of feeding. Mothers, who were blind to the hypotheses and brand of formula in the bottle, fed their infants Nutramigen on one test day and Alimentum on the other; the order was counter-balanced within groups. The amount of formula consumed by the infant was recorded and the entire feeding was videotaped (for all but three infants) to determine the length of each feed.

Statistical analyses

To determine whether there were significant differences among the three groups, a repeated measures analysis of variance (ANOVA) was conducted with formula group as the grouping factor and type

of formula fed during the feed as the within-subjects factor. All summary statistics are expressed as mean \pm SEM.

Results

Subject characteristics

There was no significant difference among the groups in the ages of the mother. Nor were there differences in the ages, weights and lengths of the infants.

Infants' feeding behaviors

There was a significant interaction between the feeding history of the infants and their acceptance of the two hydrolysate formulas [$F(2,46) = 8.96, P < 0.0005$]. Infants who were currently being fed the milk-based formulas rejected both brands of the hydrolysate formulas equally [intake, paired $t(12) = 0.61, P = 0.55$; length of feed, paired $t(12) = 0.54, P = 0.60$]. These infants drank significantly less Nutramigen than Nutramigen-exposed infants ($P < 0.01$) and less Alimentum than Alimentum-exposed infants ($P = 0.04$).

As shown in Figure 1, the protein-hydrolysate-fed infants preferred the brand of hydrolysate that they were currently being fed. That is, infants who were currently being fed Alimentum preferred Alimentum to Nutramigen [intake, paired $t(15) = 2.70, P = 0.016$; duration of feed, paired $t(12) = 43.40, P = 0.005$]. In contrast, infants who were currently being fed Nutramigen ingested significantly more of [paired $t(19) = -2.87; P = 0.009$] and spent a longer time feeding [paired $t(19) = -2.37; P = 0.029$] the Nutramigen when compared to the Alimentum.

Discussion

The present study was designed to ask whether early feeding with two separate varieties of hydrolysate formulas would differentially modify flavor acceptance. The research provided clear evidence in the affirmative: infants fed on one or another brand of hydrolysate formula significantly preferred that familiar formula to the alternative unfamiliar formula. In other words, the acceptance pattern that develops is specific to the flavor profile experienced. The control infants, fed only on milk-based formula, were equally reluctant to accept either hydrolysate formula, a result consistent with previous

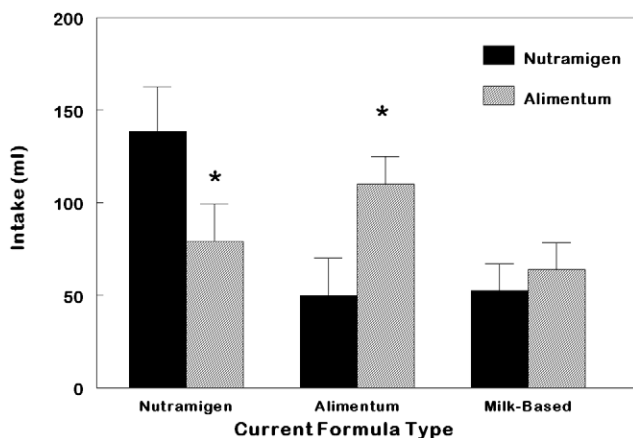


Figure 1 The amount (ml) of Nutramigen (black bars) and Alimentum (hatched bars) consumed during a single feed by infants whose regular formula was Nutramigen, Alimentum or a milk-based formula. * $P < 0.05$ when compared to Nutramigen.

research (Mennella and Beauchamp, 1996, 1998; Mennella *et al.*, 2003).

The effects of these experiences appear to be long-lived. Children aged 4–5 years who were fed hydrolysates during their infancy exhibited more positive responses to sensory attributes associated with them (e.g. sour taste, aroma) several years after their last exposure to the formula when compared with same-aged children without such experience (Liem and Mennella, 2002; Mennella and Beauchamp, 2002). Consistent with these findings is a recent study on children and adults with phenylketonuria (PKU). The dietary regimen to treat PKU consists of a hydrolysate formula that is specifically treated with charcoal to remove most of the phenylalanine. When given a choice, PKU children and adolescents preferred their bad-tasting formula to that of the new formulation that was more palatable to naive children and adults (Owada *et al.*, 2000). In other words, the characteristic flavor of the formula experienced in early life is 'imprinted' and remains as a preference for a considerable time.

These findings demonstrate that exposure to the specific flavors (tastes, retronasal olfactory stimuli) that differentiate the two commercial infant formulas influences relative acceptance of the formula. Still to be determined are the effects of varying the timing of the experience, the sensory components that are critical to modifying acceptance and the long-term effects of such exposure.

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