Human Infants Learning by Prenatal and Postnatal Flavor

Mogridge J, Thomas R A and Martinez Bakketeig

Department of Community Medicine, Norwegian University of Science and Technology, N-7489 Trondheim, Norway

*Corresponding Author: Thomas R A, Department of Community Medicine, Norwegian University of Science and Technology, N-7489 Trondheim, Norway

Citation: Human Infants Learning by Prenatal and Postnatal Flavor. Am J Nur & Pract. 2018; 1(1): 001-006

Submitted: 2 February 2018; Approved: 18 February 2018; Published: 19 February 2018

Abstract

**Background:** Flavors from the mother’s diet during pregnancy are transmitted to amniotic fluid and swallowed by the fetus. Consequently, the types of food eaten by women during pregnancy and, hence, the flavor principles of their culture may be experienced by the infants before their first exposure to solid foods. Some of these same flavors will later be experienced by infants in breast milk, a liquid that, like amniotic fluid, comprises flavors that directly reflect the foods, spices, and beverages eaten by the mother. The present study tested the hypothesis that experience with a flavor in amniotic fluid or breast milk modifies the infants’ acceptance and enjoyment of similarly flavored foods at weaning.

**Methods:** Pregnant women who planned on breast-feeding their infants were randomly assigned to 1 of 3 groups. The women consumed either 300 mL of carrot juice or water for 4 days per week for 3 consecutive weeks during the last trimester of pregnancy and then again during the first 2 months of lactation. The mothers in 1 group drank carrot juice during pregnancy and water during lactation; mothers in a second group drank water during pregnancy and carrot juice during lactation, whereas those in the control group drank water during both pregnancy and lactation. Approximately 4 weeks after the mothers began complementing their infants’ diet with cereal and before the infants had ever been fed foods or juices containing the flavor of carrots, the infants were videotaped as they fed, in counterbalanced order, cereal prepared with water during 1 test session and cereal prepared with carrot juice during another. Immediately after each session, the mothers rated their infants’ enjoyment of the food on a 9-point scale.

**Results:** The results demonstrated that the infants who had exposure to the flavor of carrots in either amniotic fluid or breast milk behaved differently in response to that flavor in a food base than did nonexposed control infants. Specifically, previously exposed infants exhibited fewer negative facial expressions while feeding the carrot-flavored cereal compared with the plain cereal, whereas control infants whose mothers drank water during pregnancy and lactation exhibited no such difference. Moreover, those infants who were exposed to carrots prenatally were perceived by their mothers as enjoying the carrot-flavored cereal more compared with the plain cereal. Although these same tendencies were observed for the amount of cereal consumed and the length of the feeds, these findings were not statistically significant.

**Conclusions:** Prenatal and early postnatal exposure to a flavor enhanced the infants’ enjoyment of that flavor in solid foods during weaning. These very early flavor experiences may provide the foundation for cultural and ethnic differences in cuisine

Introduction

Throughout human history, what a woman experiences during pregnancy and lactation has been believed to somehow influence her child’s character for a lifetime. For example, stresses or shocks experienced by the pregnant mother, as well as faulty diets, were assumed to cause mental imbalances in the child. That this notion extends to early postnatal life is suggested by the rich folklore that surrounded the choice of wet nurses. Before the 1800s, many believed that the lactating mother or wet nurse, through her milk, provided the infant

with not only nourishment but characteristics of her personality, such as her ideas, intelligence, speech, and emotional qualities.4,5

During the past few decades, a series of experiments demonstrated that fetal learning does indeed occur.1,6 The fetus not only learns the speech characteristics of the mother prenatally,7 but shortly after birth, infants prefer their mother’s voice,8 a passage recited to them prenatally,7 and the theme music of a soap opera watched by their mothers during pregnancy.9 The ability to detect other sensory stimuli, such as tastes and smells, also seems to be developed before birth.10

Within days of birth, human infants will orient toward the odor of their own amniotic fluid, which suggests that prenatal sensory experiences can bias the newborn’s behaviors and preferences.11,12 Moreover, the environment from which the newborn came, the amnion, contains compounds derived from flavors of foods eaten by the pregnant mother.13,14 Such exposure to dietary transmitted flavors (eg, garlic, anise) in amniotic fluid has been shown to influence the newborn’s facial, mouthing, and orienting responses to the flavor in the short-term.15,16 Because some of these same flavors will later be experienced in breast milk,17–20 the fetus and breast-fed infant experience the flavors of their mother’s diet before their first exposure to these flavors in solid foods. The present study expands on these findings and provides the first experimental evidence in humans that prenatal flavor experiences enhance the acceptance and enjoyment of similarly flavored foods during weaning. It also shows that postnatal exposure has similar consequences. Thus, very early flavor experiences may provide the foundation for cultural and ethnic differences in cuisine.

METHODS

Participants

Forty-six pregnant mothers (39 white, 4 black, 2 Hispanic, 1 Asian) who were in their last trimester of pregnancy and who planned to breastfeed their infants were recruited from advertisements in local newspapers; 65% were multiparous. All but 1 delivered a healthy singleton at term and successfully breastfed their infants during the exposure periods; the remaining mother had fraternal twins. Six additional mothers participated in the study but were disqualified either because they did not breastfeed long enough (n = 2), the infant refused to eat during both testing days (n = 3), or the mother did not comply with the experimental procedures (n = 1). All procedures were approved by the Committee on Studies Involving Human Beings at the University of Pennsylvania.


Exposure Procedures

The pregnant women were randomly assigned to 1 of 3 groups. During the last trimester of pregnancy (33.2 ± 0.3 weeks of gestation), the women were given either bottles of water (Naya, St-André Est, Québec, Canada) or cartons of frozen organic carrot juice (Ferraro, Glendora, CA) and instructions regarding the time of day (10 am to 2 pm) to drink the beverage. Carrot flavor was chosen as the stimulus for several reasons. First, it is a flavor that is transmitted to human milk and is quite distinctive.20 Second, it was easy to ensure that the nursing mothers’ only source of this flavor was under experimental control.20 Finally, carrot flavor has been added to the infants’ pap during the time of weaning for centuries.21

The women consumed either 300 mL of carrot juice or water daily for 4 days per week for 3 consecutive weeks during the last trimester of pregnancy and then again during the first 2 months of lactation (1.3 ± 0.1 months). As shown in Fig 1, the mothers in 1 group drank carrot juice during pregnancy and water during lactation (CW; n = 16); mothers in another (WC) group did the opposite (n = 17); whereas those in the control group drank water during both exposure periods (WW; n = 14). There were no significant differences among the groups in the timing of the exposure periods during pregnancy or lactation (F[2,43 df] = 1.42; P = .25). Mothers refrained from eating carrots or drinking carrot juice during and between the 2 exposure periods. To encourage and verify compliance, mothers maintained diet logs of all the foods and beverages that they ate during the exposure period and daily phone or e-mail contact was made with each woman.

<table>
<thead>
<tr>
<th>Type of Beverage Consumed by Mother During:</th>
<th>Infant Preference Tests:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Last Trimester of Pregnancy</td>
<td>First Months of Lactation</td>
</tr>
<tr>
<td>Group CW CARROT WATER</td>
<td>Carrot-Flavored vs Plain Cereal</td>
</tr>
<tr>
<td>Group WC WATER CARROT</td>
<td>Carrot-Flavored vs Plain Cereal</td>
</tr>
<tr>
<td>Group WW WATER WATER</td>
<td>Carrot-Flavored vs Plain Cereal</td>
</tr>
</tbody>
</table>

Figure: The design of the experimental protocol for the 3 groups of participants. The women consumed either 300 mL of carrot juice or water daily for 4 days per week for 3 consecutive weeks during the last trimester of pregnancy and then again during the first 2 months of lactation. The mothers in 1 group (CW) drank carrot juice during pregnancy and water during lactation (n = 16); mothers
in another (WC) drank water during pregnancy and carrot juice during lactation (n = 17); whereas those in the control group (WW) drank water during both exposure periods (n = 14). Approximately 4 weeks after the mothers began complementing their infants’ diet with cereal but before the introduction of carrot-flavored foods or beverages, the infants, who were ~6 months of age, were videotaped at the Monell Center as they fed, in counterbalanced order, cereal prepared with water (1 part cereal, 1 part water) during 1 test day and cereal prepared with carrot juice (1 part cereal, 1 part carrot juice) during another.

The characteristics of each group are listed in Table 1. There were no significant differences between the groups in the ages of the mothers (F[2,43 df] = 2.21; P = .12) or infants (F[2,43 df] = 0.54; P = .95), the infants’ body mass index (BMI); F[2,43 df] = 2.31; P = .11), or the sex ratio of the infants (χ2 [2 df] = 1.70; P = .43). There was not a significant interaction between group and sex on the infants’ BMI (F[2,40 df] = 1.66; P = .20). However, there was a significant effect of sex (F[1,40 df] = 4.60; P = .04); posthoc analysis revealed that overall boys tended to have a larger BMI than did girl infants of this age (F[1,44 df] = 3.67; P = .07).

<table>
<thead>
<tr>
<th>Type of Beverage Consumed by the Mother During</th>
<th>Group CW Carrot Water</th>
<th>Group WC Water Carrot</th>
<th>Group WW Water Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mothers’ age in y</td>
<td>Mean ± SEM</td>
<td>29.0 ± 1.6</td>
<td>31.9 ± 1.0</td>
</tr>
<tr>
<td>Infants’ age in mo at cereal test</td>
<td>Mean ± SEM</td>
<td>5.6 ± 0.2</td>
<td>5.7 ± 0.4</td>
</tr>
<tr>
<td>BMI</td>
<td>Mean ± SEM</td>
<td>17.3 ± 0.5</td>
<td>16.2 ± 0.4</td>
</tr>
<tr>
<td>Sex of infants</td>
<td>girls:boys</td>
<td>4:11</td>
<td>7:10</td>
</tr>
<tr>
<td>Number of mother–child pairs</td>
<td>15</td>
<td>17</td>
<td>14</td>
</tr>
</tbody>
</table>

**Testing Procedures**

A within-participants design that controlled for time of day was implemented. Approximately 4 (± 0.5) weeks after the mothers began complementing their infants’ diet with cereal and before the introduction of carrot foods to their diet, the infants, who were 5.7 ± 0.2 months old, were videotaped at the Monell Center as they fed, in counterbalanced order, cereal prepared with water (1 part cereal, 1 part water) during 1 test day and cereal prepared with carrot juice (1 part cereal, 1 part carrot juice) during another. These test sessions were separated by, on average, 4 (± 0.5) days. All liquids were room temperature before cereal preparation. None of the infants had ever been fed carrot juice or any foods containing carrots. There were no significant differences among the groups in the number of weeks the infants had been fed cereal (F[2,43 df] = 0.32; P = .73). The vast majority of the mothers (n = 39) were still nursing at the time of testing; the remaining 7 women had weaned their infants from the breast, on average, 3.5 ± 0.6 weeks before the first test session.

To minimize possible effects attributable to different levels of satiation and familiarization, each test session began at approximately the same time of day that the infants were usually fed cereal and the mothers drank the juice or water during the exposure periods (10 am to 2 pm). The infants were last fed ∼2.5 ± 0.2 hours before testing and there was no significant difference in this duration of time between the 2 test sessions (paired t [45 df] = 0.35; P = .73). In addition, the type of cereal offered was the brand that the infant was currently being fed and, thus, was familiar.

The infants sat in a chair that had a tray attached to its arms and their mothers fed them with utensils and the infants wore bibs that were identical to those used at home.22 The mothers refrained from talking or making faces during the feeding sessions to eliminate any potential influence of the mother’s verbal or facial responses on her infant’s behaviors; replays of the videotapes verified that this was indeed the case. Mothers were instructed to feed the infants at their customary pace until they refused the cereal 3 consecutive times, using the criterion that the infant exhibited such behaviors as turning his or her head away, pushing the spoon away, crying, or becoming playful. The experimenter, who was unaware of the experimental conditions of the participants, then signaled to the mother to stop feeding. The experimenter sat behind the video camera, which was placed at the far corner of the testing room ~10 to 12 feet from the mother–infant dyad and was out of view of the mother and her infant.

Immediately after each feeding session, the mothers, who were unaware of the hypothesis of the study, then rated, how much that they thought their infant liked the cereal on a 9-point scale. Intermediate ratings were to be marked at the appropriate locations between the extremes such that ratings could range from 1 (did not like at all) to 9 (liked very much). The infants’ behaviors were monitored by videotape and the amount of cereal consumed by the infant was assessed by weighing the bowl immediately after each feeding session.

**Cite this article:** Human Infants Learning by Prenatal and Postnatal Flavor. Am J Nur & Pract. 2018; 1(1): 001-006
DISCUSSION

This is the first experimental evidence in humans that prenatal flavor experiences influence postnatal responses to that flavor in solid foods. The data also provide additional evidence that early postnatal experience has similar effects and, thus, highlight the importance of a varied diet for both pregnant and lactating women. The differences observed in the infants’ relative enjoyment, as inferred from facial expressions made during feeding carrot-flavored cereal, seem not to be attributable to the mothers’ eating habits or attitudes toward foods because there were no significant differences among the 3 groups of mothers on any of these measures.

Two related lines of evidence support the conclusion that prenatal and postnatal sensory experiences influenced the acceptance of carrot flavor in solid foods. First, only those infants who were exposed to carrot flavor either prenatally (CW) or postnatally (WC) displayed fewer negative facial responses while eating the carrot-flavored cereal relative to the plain; this was not the case for the control (WW) infants. Second, only the mothers of the 2 experimental groups (although this was significant only for the CW group) rated their infants’ enjoyment of the carrot-flavored cereal as exceeding that of the plain cereal. In contrast, control mothers rated their infant’s enjoyment of the plain and carrot-flavored cereal almost identically. These ratings by the mothers reflected, in part, how much and how long their infants ate the carrot-flavored cereal.

The present study aimed to experimentally control for a number of factors that could bias the infants’ behaviors. For example, testing took place at the same time of day that the infants were usually fed this familiar brand of cereal and their mothers drank the juice or water during the exposure periods, and the duration of time since the infants were last fed was controlled for to minimize effects attributable to different levels of satiation and familiarization. In addition, the infants determined when the feeding ended because the test session terminated when the infants rejected the cereal on 3 consecutive occasions. Mothers, who were unaware of the hypothesis being tested, were not told how much their infants consumed during each of the 2 test sessions that were separated by an interval of ~4 days. Their ratings of how much their infants enjoyed the cereal reflected, in part, how much the infants ate and how long they fed, as suggested by the significant correlations between maternal ratings and these 2 behaviors. Therefore, it is unlikely that group differences in maternal ratings and the infants’ facial responses were attributable to changes in the infants’ interaction with their mothers or to exper
imental bias. Rather, it seems that our findings are attributable to experiential effect of carrot exposure in amniotic fluid or mothers' milk.

Although we have not demonstrated experimentally that carrot flavor is transmitted from the pregnant mother into her amniotic fluid, this is highly likely for several reasons. First, we demonstrated earlier that at least 1 flavor consumed by pregnant women, garlic, does enter amniotic fluid to levels detectable by the adult human nose.14 Second, we have shown that carrot flavor,20 like garlic17 and several other flavors,18,19 is transmitted from the nursing mother's diet to her milk. Thus, the basis for the effects of prenatal carrot feeding is most likely via the influence of fetal exposure to carrot flavor.

The findings that early flavor experience impacts on later food enjoyment by infants are consistent with animal model studies that demonstrate that early exposure to flavors serves to heighten the acceptability of those flavors in foods and even facilitates weaning, as has been shown in swine.26 Young animals prefer flavors that were experienced during either gestation or lactation.27–30 Such redundancy of dietary information has importance biologically because it provides complementary routes of transferring information on the types of foods available in the environment, should the mothers' diet change.27 Although it is likely that such experience influences acceptance at older ages in humans, this hypothesis remains to be tested.

The flavor of a food includes, among other sensory stimuli, the oral sensation of taste and the retronasal sensation of smell. It has been suggested that relative to taste, where hedonic tone and liking are more hard-wired, liking for olfactory components of flavor is largely determined by individual experience.31 Although the importance of early experience in setting likes and dislikes in omnivores, such as humans, has been disputed,32 we suggest that prenatal and early postnatal exposure, at the least, predisposes the young infant to favorably respond to the now familiar flavor, which, in turn, facilitates the transition from fetal life through the breastfeeding period to the initiation of a varied solid food diet.33 In this way, culture-specific flavor preferences are likely initiated early in life.33,34 Significant traces of this may remain as children become adults and pass on their food habits to the next generation, often via amniotic fluid and breast milk-associated cues.

References
