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Human Fetal "Olfactory" Learning

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Abstract: The ability of the human fetus to learn about auditory stimuli is well documented. By comparison however there has been virtually no study of its ability to learn "olfactory" stimuli despite much research in other species. This study examined the ability of fetuses to learn an odour, garlic, experienced only prenatally, via the mother's diet. When tested 20 hours after birth infants exposed to garlic during pregnancy showed a different response to garlic compared to individuals not prenatally exposed. Individuals not prenatally exposed to garlic avoided the smell whereas those prenatally exposed now showed no aversion. The study extends our knowledge of human fetal abilities by demonstrating fetal "olfactory" learning. Prenatal olfactory learning may serve a biologically essential function that of ensuring successful breast feeding.

Zusammenfassung: *Fötales Geruchslernen beim Menschen.* Die Fähigkeit des menschlichen Fötus auf Hörreize hin zu lernen ist gut dokumentiert. Im Vergleich dazu gibt es keine Studie über diese Lernfähigkeit im Bereich des Riechens beim Menschen, obwohl dies bei anderen Arten vielfältig untersucht ist. Diese Studie untersuchte die Fähigkeiten von Föten einen Duft zu lernen, und zwar den von Knoblauch, der nur vorgeburtlich über die Nahrung der Mutter vermittelt war. Als wir 20 Stunden nach der Geburt die Kinder dem Knoblauchgeruch aussetzten, zeigten diejenigen, die mit Knoblauch während der Schwangerschaft eine Erfahrung hatten, ein anderes Verhalten als diejenigen, denen Knoblauch unbekannt war. Letztere zeigten ein Abwehrverhalten gegen Knoblauch, während erstere keine Ablehnung zeigten. Die Studie weitet unser Wissen über die Fähigkeit des menschlichen Föten aus, indem sie Geruchslernen nachweist. Pränatales Geruchslernen könnte eine wesentliche biologische Funktion haben, und zwar die Sicherung eines erfolgreichen Stillvorganges.

Introduction

There is now little doubt that the human fetus is capable of learning. A number of studies using different paradigms, habituation (Leader, Baille, Martin & Vermeulen 1982), classical conditioning (Spelt 1948), exposure learning (DeCasper & Fifer 1980, Hepper 1991) have all demonstrated fetal learning. One common

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thread that runs through these studies is that they have all used auditory stimuli. This is in contrast to studies of animal prenatal learning where chemosensory stimuli (olfactory and gustatory are not distinguished since in the prenatal environment it is likely that both sense will be stimulated) have been the stimuli of choice. Demonstrations of prenatal olfactory learning have been reported throughout the animal kingdom, in mammals (Smotherman & Robinson 1985), birds (Tolhurst & Vince 1976, Vince 1976), amphibians (Hepper & Waldman 1992), and even invertebrates (Caubet, Jaisson & Lenoir 1992).

The newborn infant has a functioning olfactory system and is capable of fine olfactory discriminations (Steiner 1979). Newborns can recognise their own mother by smell soon after birth (Macfarlane 1975, Porter 1991). Whilst there have been suggestions that this learning may commence prenatally (Porter 1991) there have been few studies examining this directly.

Examination of fetal olfactory responsiveness may be undertaken through the manipulation of the maternal diet. Maternal dietary substances may reach the fetus by direct infusion into the amniotic fluid or may cross the placental barrier to be present in the fetus's blood (Hepper 1988). Schaal and Orgeur (1992) reported a preliminary study in which a mother in the last 12 days of her pregnancy ate capsules filled with cumin seeds. Her female newborn, when tested 12 hours after birth showed a greater amplitude of heart rate accelerations to the smell of cumin than to citral or air.

This is suggestive, but is not conclusive, of the fact that the human fetus possesses the ability to learn about chemosensory stimuli. It is the aim of this study to examine human fetal olfactory learning. This study examined the fetus's ability to learn the smell of garlic. Essence of garlic (allyl sulphide) is carried in the blood (Maruniak 1983a) and may be perceived (smelled) directly from its presence in the blood (Maruniak 1983b). Thus garlic consumed by the mother in her diet may be experienced by the fetus (Hepper 1988, Nolte, Provenza, Callan & Panter 1992). Garlic may pass into the mother's blood stream cross the placenta into the fetus's blood stream and then stimulate its nasal chemoreceptors. Alternatively garlic may pass directly into the amniotic fluid and as the fetus swallows and "breaths" amniotic fluid the garlic stimulates receptors in the mouth (taste) and nose (smell). Experience by whatever route may result in the fetus learning this chemosensory stimulus. This possibility was examined here.

Method

Subjects

Twenty mothers were recruited from the antenatal clinic of Royal Maternity Hospital, Belfast. Mothers were screened before the study for their liking or disliking of garlic and the role it played in their diet. Mothers were selected and placed into one of two groups. In the first group (garlic group) were mothers who liked garlic and would use garlic in their meals at least 3/4 times per week. Ten mothers were found who fulfilled this criteria. During the last month of pregnancy these mothers had a minimum of 4 meals per week which contained fresh garlic. The second group (non-garlic group) were mothers who disliked garlic and never ate meals containing garlic. Ten mothers fulfilled his criterion. Both groups of mothers had

normal singleton pregnancies. Their babies were born at term with Apgar scores of greater than 7 at 1 and 5 minutes. There were no obstetric complications prior to, or during, delivery.

Procedure

Infants were tested between 15 and 28 hours after birth. Mean age (in hours ±s.e.) of testing for the "garlic" group and the "non-garlic" group was 19.3 (±1.26) and 20.7 (±1.34) respectively. An unpaired t-test revealed no difference between the two groups in age at testing ($t[18] = 0.754$, n.s.). Infants were tested in their cots and given a 2 choice test between garlic (1 mg of garlic paste) on cotton wool or unadulterated cotton wool (neutral stimulus). These stimuli were placed either side of the baby's head level with its mouth and stuck to the side of the cot. For half the babies in each group the garlic was on the baby's left and for the other half on the baby's right. All babies were awake when testing began and had recently (within the last 5-15 minutes) had a feed. The baby's head was placed in the midline and left for 3 minutes. The time the baby spent with its head either facing the garlic, or facing the neutral stimulus was recorded. When the baby's head was in the midline (±15 degrees) no time was recorded. A preference score for garlic for each baby was calculated by dividing the time spent facing the garlic stimulus by the sum of the time spent facing the garlic stimulus + the time spent facing the neutral stimulus. This sum was then multiplied by 100 to give the percentage time spent by the newborn facing the garlic stimulus.

Results

An unpaired t-test was used to compare the preference for garlic exhibited by newborns whose mothers had eaten garlic when pregnant to the preference for garlic exhibited by newborns whose mothers had not eaten garlic when pregnant. The results indicated a significant difference between the two groups, $t[18] = 2.663$, $p = 0.016$. Newborns of mothers who did not eat garlic during pregnancy showed a strong aversion to garlic (35.57% garlic preference ±7.17). Newborns of mothers who ate garlic during pregnancy showed a slight preference for garlic (60.00% garlic preference ±5.72). Thus although prenatal exposure did not result in a preference for garlic it did change the newborn's preference from one of aversion with no prenatal experience to one of a slight preference.

Discussion

The results indicate that prenatal exposure to garlic changes the newborn's preference for that stimulus. Newborns unfamiliar with garlic show a strong aversion to the stimulus whereas newborns who had been exposed to the garlic prenatally via the mother's diet show a slight preference.

The results support data from animal studies which have indicated that maternal dietary substances cross the placenta and reach the fetus to stimulate its chemosensory receptors (Hepper 1988). This exposure subsequently changes the individual's preference.

It is possible that the newborns could have become familiar with the garlic after birth. No mothers had a meal of garlic and thus newborns could not have learned it by this route. In this sample none of the babies were breast feed. It has been shown that maternal dietary substances will be present in both the breast milk and amniotic fluid (Hepper in press, Menella & Beauchamp 1991, Stafford, Hornung & Zlatkis 1976). Babies who were breast fed may have the opportunity to learn about garlic from breast feeding. In this case however as none of the infants were breast fed this possibility can be excluded.

A final possibility is that the garlic could have been learned as the infant learned about its mother's olfactory signature in general. Whilst previous studies have shown that infants can recognise their mother's smell the role of postnatal experience has yet to be fully elucidated. One study found that newborns could recognise their mothers odour only if breast fed. Bottle fed infants were unable to discriminate between their mother and an unfamiliar lactating female (Cernoch & Porter 1985). As infants in this study were bottle fed, the opportunity to learn about garlic from their mother's odour may be reduced.

The most likely possibility is that newborn's preference for garlic was affected by its prenatal exposure to the garlic in its mother's diet.

The functions of prenatal olfactory learning have now to be elucidated. Two possibilities are suggested here. First, it may enable the mother's olfactory signature to be learned (cf. Porter 1991) beginning the process of attachment. Second, it may ensure the newborn begins breast feeding. The same processes by which the mother's diet flavours the amniotic fluid will also flavour the mother's breast milk (Stafford, Hornung & Zlatkis 1976). The fetus may learn about the taste and/or smell of its amniotic fluid. Its mother's breast milk, due to the same flavouring processes will posses a similar taste and/or smell. Thus when the infant is put to the breast for the first time it recognises the mother's milk as a familiar taste and/or smell, one it has been exposed to for the previous 9 months. Thus the individual may be primed in the womb to recognise its mother's breast milk, reducing the chances of the newborn rejecting this substance: a substance essential for its survival.

The study expands our knowledge of human fetal abilities on two fronts. First, it reveals yet another area of sensory stimulation the fetus is exposed to, namely olfaction and gustation. Substances in the mother's diet will pass into the fetus's environment. Second, the results indicate fetal learning abilities are not restricted to the auditory modality, but are also present in the chemosensory modality.

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