Neuroscience Letters 673 (2018) 7–11

Contents lists available at ScienceDirect

Neuroscience Letters

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

Research article

Influence of prenatal pre-exposure to an odor on intake behavior of an aversive solution in newborn rats

Giselle V. Kamenetzky[a,b], Andrea B. Suárez[a,b], María Celeste Ifran[a,b,*], Michael E. Nizhnikov[e], Ricardo M. Pautassi[c,d]

[a] Laboratorio de Psicología Experimental y Aplicada, Universidad de Buenos Aires, Instituto de Investigaciones Médicas (IDIM – CONICET – UBA), Argentina
[b] Centro de Altos Estudios en Ciencias Humanas y de la Salud (CAECIHS-UAI), Universidad Abierta Interamericana, Buenos Aires, Argentina
[c] Instituto de Investigación Médica Mercedes y Martín Ferreyra, CONICET, Universidad Nacional de Córdoba, Córdoba, Argentina
[d] Facultad de Psicología, Universidad Nacional de Córdoba, Córdoba, C.P 5000, Argentina
[e] Department of Psychology, Southern Connecticut State University, United States

ARTICLE INFO

Keywords:
Quinine
Neonate rat
Odor pre-exposure
Prenatal exposure

ABSTRACT

Early pre- or postnatal sensory experiences significantly influence flavor preference and food intake, and can induce liking for innately unpalatable flavors. Previous work found that newborn rats stimulated with an odor experienced shortly after birth exhibited heightened intake and seeking towards an artificial nipple containing quinine. This result suggests that odors made familiar trough early postnatal pre-exposure can shift the motivational value of unconditional stimuli. The objective of the current study was to assess the effect of an odor (lemon) experienced in-utero on the first intake responses towards an artificial nipple supplying quinine. The hypothesis, which was corroborated, was that stimulation with the olfactory stimulus experienced in-utero would increase the newborn's intake and grasp responses to the artificial nipple containing quinine. Exposure to the odor that had been pre-exposed in utero increased quinine intake and seeking (i.e., latency to grasp and total time in contact with the nipple, as well as number of and mean duration of nipple grasps) in 3-h-old pups. These results replicate those previously found with postnatal odor pre-exposure, and extend the phase for pre-exposure to the prenatal stage.

1. Introduction

Associative and non-associative odor learning in altricial species, such as the rat, facilitates the dam-pup dyad interaction during the first postnatal weeks. The odor of the dam is affected by the diet, and pups are born without fully developed visual and auditory systems. Odor learning, and smell in a broader sense, is thus key to find the nest and maternal nipple [8]. Tastes are associated with odors, and both stimuli constitute flavors [7].

The gustatory and olfactory systems are not yet mature during the latest stages of fetal life; yet this does not prevent detection and differentiation of, and learning from, the chemosensory cues present in the amniotic fluid [1]. These experiences affect postnatal behavioral responses and physiological reactions to odors and flavors [2]. It occurs inasmuch as flavors from the mother's diet are transmitted to the amniotic fluid and to her milk later on [3]. Prenatal learning of flavors may have been favored and selected through evolution because it favors the infant's acceptance of food and flavors ingested by his/her mother. Postnatal preference for flavors experienced during gestation has been observed in several mammalian species, such as humans [4], rats [2], cats [5] and piglets [6].

Mennella, Jagnow and Beauchamp [9] assessed whether exposure to a flavor during human gestation affected postnatal reactions to foods that had a similar flavor. Pregnant women consumed carrot juice during the last trimester of pregnancy. Their infants were assessed, when they were almost six months old, for responsiveness to cereals prepared with carrot juice. The authors reported significantly increased levels of enjoyment of that food in the children whose mothers had consumed carrot juice during pregnancy, compared to those of women who had not drunk carrot juice nor eaten carrots during that period.

Early pre- or postnatal sensory experiences not only influence preference for food or flavors that are part of the regular diet of the organism, but also induce liking for typically unpalatable flavors [4]. Kamenetzky, Suárez, Pautassi, Mustaca and Nizhnikov [10] pre-exposed rats, immediately after birth, to a lemon scent. Three hours later, the newborns were stimulated with a surrogate nipple odorized with

* Corresponding author at: Corresponding autor.: Instituto de Investigaciones Médicas Lanari (IDIM – CONICET – UBA), Combatientes de Malvinas 3150, Ciudad Autónoma de Buenos Aires, C.P 1427, Argentina.
E-mail address: MariaCeleste.Ifran@Alumnos.uai.edu.ar (M.C. Ifran).

https://doi.org/10.1016/j.neulet.2018.02.053
Received 18 December 2017; Received in revised form 14 February 2018; Accepted 23 February 2018
Available online 24 February 2018
0304-3940/

lemon odor that provided either saccharin (0.1% or 0.2%) or an aversive quinine solution (0.1% or 0.2%). Greater intake and behavioral responsiveness, compared to a control, non-preexposed group, was found exclusively for the 0.1% quinine solution. It is conceivable that this might be due to the pre-exposed olfactory stimulus changing the hedonic value of this typically aversive substance [11]. This effect might be especially important when looking at preference of alcohol after exposure in the womb. Alcohol has a distinct bitter taste and it has been shown that gustatory stimulation with a quinine-sucrose compound evokes electrophysiological responses similar to those evoked by the drug [12].

The animal literature shows an extensive body of research indicating that prenatal exposure to alcohol produces long lasting memories in the organism that, along with early postnatal experiences with the drug, enhance its intake and sensory discrimination during infancy and adolescence [2,3,13–17]. For instance, Domínguez, López and Molina [18] found an increase in alcohol intake and lower duration of head and forelimb movements towards the odor of alcohol, in infant rats born from dams given 1 or 2 g/kg daily alcohol doses during gestational days (GD) 17–20, as compared to pups derived from vehicle-treated dams. This effect generalized to a sucrose-quinine compound, the psychophysical equivalent of ethanol for the rat [12]. These results suggest that fetuses can process the sensory attributes of alcohol and, as a result, encode specific memories that alter subsequent, postnatal responsiveness towards the drug.

Pre-exposure studies that employ alcohol are subjected to an important caveat. This drug has a distinctive flavor yet exerts potent pharmacological effects that can, by themselves, facilitate subsequent alcohol acceptance [19]. Yet pre-exposure to other flavor or tastants, that lack pharmacological activity, yield similar results. Increased preference for garlic odor was found in pups whose mothers had consumed garlic during gestation, compared to offspring of mothers who had not ingested garlic [20]. Similarly, Nicholaides et al. [21] found greater salt appetite in adult offspring of dams that had consumed a diet rich in salt during gestation. In an intriguing study, Smotherman [22] assessed consumption of an apple juice solution in juvenile rats that had been (or not) exposed to the flavor on day 20 of gestation, via injection into the amniotic fluid. Animals pre-exposed to the solution exhibited significantly higher levels of intake than either untreated pups or pups pre-exposed to saline. Rat fetuses receiving pairings of apple juice solution and lithium chloride (a potent emetic agent) in-utero showed conditioned taste aversion to that solution when they were evaluated at postnatal day 10 [23]. Altogether, these studies indicate that in-utero exposure to flavors during the last days of gestation can yield memories that last up to adulthood and generate greater preferences for those flavors, or increased responsiveness to its sensory attributes [2].

The present study determined whether odor pre-exposure during late gestation, via contamination of the amniotic fluid, could yield the same effects on quinine intake as the odor pre-exposure shortly after birth. We assessed the effect of stimulation with an odor that had been experienced in-utero, on the first responses towards an artificial nipple supplying quinine.

2. Materials and methods

2.1. Subjects

Thirty-four pups, derived from 8 Sprague–Dawley dams (Taconic, Germantown, NY) mated at the vivarium of the Department of Psychology at Binghamton University (temperature: 22 °C; 12-h light-dark cycle with lights on at 0700 h), were employed. Specifically, 18 pups were stimulated with water prenatally, and these were representative of 4 litters; whereas 16 pups (representative of 4 litters) were exposed to lemon prenatally. We aimed at using only one male and one female from each dam, yet due to logistic problems in the supply of dams, we had to use more than one male and one female from the same dam in 4 of the litters.

Vaginal smears were collected each day during a 7-day breeding period to time each pregnancy. The first day of detectable sperm was designated as embryonic day 0 (E0). All animals had ad libitum access to food (Purina Rat Chow, Lowell, MA) and water. The rats were maintained and treated in accordance with the guidelines for animal care and use established by the National Institutes of Health (1986), within an AAALAC-accredited facility.

2.2. Apparatus

The surrogate nipple was constructed with a hollow tip made of rubber and shaped conical, attached to a dental explorer and connected through a cannula to a syringe containing the solution. The syringe had a hole in the top wall, which generated a hydraulic flow that was activated and controlled by the animal when it voluntarily suctioned. The dental explorer had an alligator clip attached to the top, which had a cotton swab soaked in the lemon scent [24].

2.3. Procedure

2.3.1. Pre-exposure to the olfactory stimulus

During GD21, one hour before the C-section, the pregnant female rats were intragastrically administered with 0.015 ml/g of lemon solution (16, 8% v/v) via i.g., or with an equal volume of vehicle (distilled water). Lemon odor was chosen because it is widely used as a salient odor that is not harmful to the pups [25–27]. The pups were assigned to treatment groups in a random fashion and precautions were taken to conceal treatment assignment to the behavioral coders.

2.3.2. Caesarean section

One hour after, a C-section was performed under a continuous supply of isoflurane (Baxter, Deerfield, IL; VetEquip, Pleasanton, CA). A midline incision was made through the abdominal wall to expose the uterine horns. A small incision into each amniotic sac allowed externalization of the pups. The umbilical cord was pressed for a few seconds and then cut and the membranes were removed. Finally, each pup was placed into a plastic container (12 cm long × 12 cm wide × 6 cm high) lined with a moist, sterile gauze, on a heating pad. Once the cesarean section was completed, the anesthetized dam was sacrificed. Immediately after, pups were placed during 3 h in an odorless incubator (Microplate Incubator, Boekel Scientific, Feasterville, PA) kept at 35 °C ± 1; until the test began. The 1 h interval between gavage and C-section was meant to minimize the possibility of an association between the lemon odor and the manipulations inherent to the C-section. Our aim was to familiarize (pre-expose) pups with the lemon odor and not to condition this odor to the event of C-section.

2.3.3. Test

Before the commencement of the test, the pups were gently stimulated in the anogenital region with cotton to induce urination or defecation. Subsequently, they were weighed to the nearest 0.01 g and placed individually on a mirror maintained at 35.5 °C ± .5 °C. Then, the test began and lasted for 6 min, during which the offspring were stimulated with the artificial nipple on the perioral area, in the presence of a swab soaked in lemon essence. The experimenter held the swab at about 2 cm from the pup's snout via a dental explorer tool which, itself, was connected to the swab through a crocodile clip. Grasping the nipple allowed the pup to obtain a 0.1% quinine solution, which was selected based on our previous work [10]. Specifically, quinine acceptance is usually quite low, which made it a good fit for the present study, which assessed the possibility of observing heightened acceptance of a taste provided in contiguity with a pre-exposed odor. At the end of the session, pups were dried with a paper towel, weighed to the nearest 0.01 g and returned to incubator.

The oral grasp response involved an active movement of the head

towards the surrogate nipple, which resulted in the tip of the nipple entering the oral cavity and the mouth closing around the nipple. From this response, the following measures were obtained: a. Latency to grasp (time to first grasping response), b. total time of grasping (total time spent on the nipple or sum of the duration of all grasps), c. number of grasps (attachments initiated), and d. mean duration of an individual grasp response. Body weight gain was calculated {100 × [(post-weight − pre-weight)/pre-weight]} as an estimate of fluid consumption. The test was video recorded to later analyze the behaviors.

2.4. Data analysis

The unit of analysis was the individual pup. All variables were analyzed via factorial Analysis of Variance (ANOVA), in which sex (male, female) and group (pre-exposed, control) served as between factors. An alpha value of 0.05 was used across analyses, which were conducted via STATISTICA 6.0 (StatSoft, Tulsa, OK). The partial Eta square (η^2p) was calculated to estimate effect size of the significant main effects or significant interactions indicated by the ANOVAs.

3. Results

Visual inspection of Fig. 1 suggests that the animals pre-exposed to lemon odor in utero consumed, during the test, more quinine (Panel E) and showed higher duration (Panel A), mean duration (Panel C) and frequency of grasp (Panel B), as well as lower latency to grasp the nipple (Panel D), compared to the control group. These impressions were confirmed by the ANOVAs. Subjects pre-exposed to the olfactory stimulus showed, compared to non-pre-exposed animals, significantly greater percentage of body weight gain, $F_{1,30} = 18.57$, $p < 0.001$; and significantly greater total time of grasping $F_{1,30} = 31.27$, $p < 0.00$. The number of and mean duration of grasps was also significantly higher in pre-exposed than in control subjects, $F_{1,30} = 6.63$, $p < 0.001$ and $F_{1,30} = 7.58$, $p < 0.01$. Latency to grasp the nipple was, in turn, significantly lower in the experimental than in the control group, $F_{1,30} = 9.65$, $p < 0.005$ (Table 1). Across variables, sex did not exert a significant main effect nor was involved in any significant interaction.

Table 1
Hedges' g effect size for the significant effects yielded by the analysis conducted on intake and taste reaction responses (i.e., body weight gain, number and mean duration of grasps and latency). The asterisk (*) indicates a medium effect size (i.e., between 0.4 and 0.8).

Odor/Quinine	
%BWG	0.67*
Total time of grasping	0.76*
Number of grasps	0.67*
Mean duration of grasps	0.59*
Latency	0.70*

4. Discussion

Newborn rats stimulated with an odor pre-exposed in utero

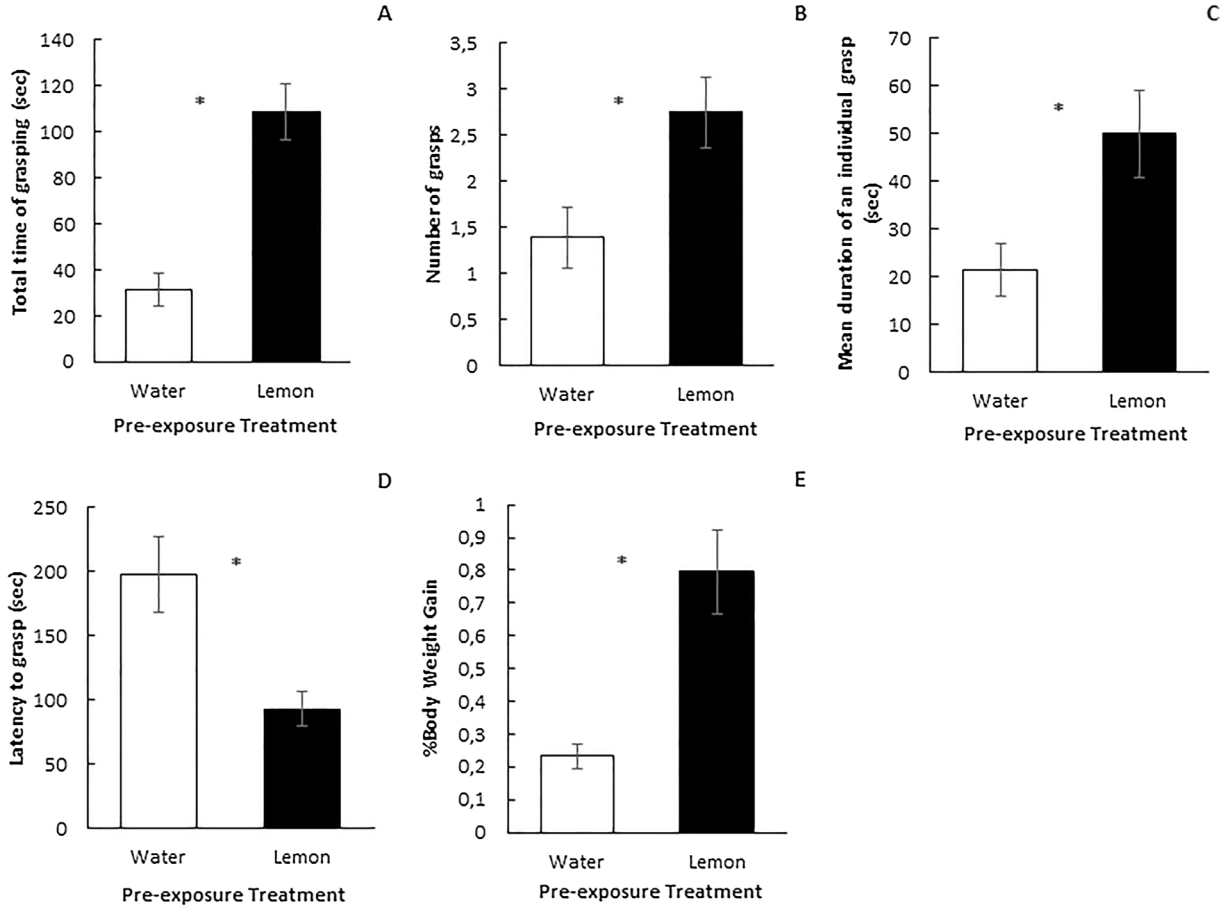

Fig. 1. Neonatal responses to the artificial nipple. (A) Total time in contact with the nipple (s), (B) number of grasp responses, (C) mean grasp duration (s) and (D) latency to grasp the artificial nipple (s); and (E) body weight gained (5) during the test, in 3-h old male and female rats that had been exposed to a water (white bars) or lemon (black bars) solution in-utero. During the 6-min test, the pups were stimulated with an artificial nipple that provided quinine (0.1%). The nipple was odorized with lemon. The vertical bars indicate the standard error of the means. Across variables, there was a significant difference (all $p < 0.05$) between the animals pre-exposed to lemon odor in utero and the control, water treated group. Sex did not exert a significant main effect nor was involved in any significant interaction. Thus, data are depicted collapsed across sex.

exhibited heightened intake and grasp responses towards an artificial nipple containing quinine, which is considered an aversive solution. The magnitude of the promoting effect of the early exposure was striking. For instance, pre-exposed animals exhibit a two-fold increase in mean grasp duration, which resulted in a four-fold increase in quinine intake, as indexed by the percentage of body weight gained during the test.

Moreover, pre-exposed animals also exhibited a significant decrease in latency to the first grasp towards the nipple, in comparison to the control, non-pre-exposed group. Altogether, these results are consistent with those found in a previous study and extend this finding (i.e., generalize the phenomenon) to the prenatal stage of development. Kamenetzky et al. [10] exposed pups to a lemon odor immediately after birth. Three hours later, it was observed that pups increased intake and behavioral responses towards 0.1% quinine, delivered via an artificial nipple odorized with lemon scent. The effect was not found if the nipple delivered 0.2% of quinine, or two concentrations of saccharine. This previous study [10] had the caveat, however, that odor pre-exposure occurred in short vicinity to the pup's birth, an event characterized by strong sensory and hormonal stimulation. It was thus not clear if the mere odor exposure was sufficient to alter subsequent behavior, or if instead, "hidden" reinforcers [2] were responsible for the effects observed. The present study, thus, represents significant advancement in our understanding of how early sensory experiences affect subsequent responsiveness to food and flavors.

The present results could be explained, at least partially, due to the activation of a protective mechanism against aversive stimuli provided in the context of nursing. Nursing activities in rodents and in other species may entail accidental biting, pushing and other aversive events. An attenuated response to aversive stimulation during the first two weeks of life may facilitate approach and attachment to the caregiver. It has been suggested that this mechanism ensures survival of pups, by preventing the development of a conditioned fear towards the mother [28,29]. Moreover, a sensitive period has been described (namely, up to approximately postnatal day 10) in which infant rats prefer an odor despite it having been paired with a moderate aversive stimulus. Neuroendocrine mechanisms that play an important role during the sensitive period are the hypofunctionality of the amygdala (the main brain structure involved in fear and aversive learning) and low levels of circulating corticosterone. The combination of both factors, as long as the stress is moderate, results in mitigation of the acquisition of learned aversions as a result of, for example, defective care [8,30]. The results found in this study suggest that the sensitive period for learning odor preferences could be extended to prenatal stages. It is conceivable that odors that become familiar due to being present during nursing (e.g., the mom's smell) are capable of shifting the motivational valence of otherwise potent aversive stimulus, such as the bitter taste employed in the present study.

Mere exposure to a given stimulus can affect subsequent responsiveness to that or other stimulus, through non-associative learning processes (i.e., habituation or sensitization) [2]. The present research adds to a growing number of studies that scrutinize how prenatal learning with chemosensory stimuli affects postnatal preference for foods and flavors. Prenatal contact with chemosensory stimuli in different mammalian species results in greater intake or preference to such stimuli during postnatal life [9,13,31–33]. Most of these studies suggest that this increased acceptance is merely due to familiarization or loss of neophobia. The originality of the results found in this study is that the pre-exposed stimulus (i.e., the lemon odor) makes pups accept not only another kind of stimulus (a taste), but particularly one that has been considered prototypically aversive (i.e. quinine).

This research indicates that 1. rat fetuses, one hour before birth are capable of processing chemosensory stimuli, 2. fetuses generate non-associative memories due to this experience, 3. These memories modulate seeking and intake behaviors during the first meal. In summary, an odor that had been experienced in utero and later accompanies quinine delivery through an artificial nipple, produces exacerbated intake responses in offspring of 3 h of life. These results relate to those gathered in human infants, who exhibit a sensitive period, before 4 months of age, during which solutions typically rejected (e.g., hydrolysate milk formulas) are accepted. Furthermore, given that the newborn rat represents a neurological model of the human in the third trimester of gestation [34], the preparation used in this study should help increase our knowledge about the interaction of odors and tastes in early stages of development.

Acknowledgments

This work was supported by grants PIP CONICET and FONCyT-PICT to GK and RMP < , by a grant of the Universidad Abierta Interamericana to GK; and by NIAAA grants AA018164, AA017823, AA011960, AA01309, and AA017823.

References

[1] J.C. Molina, N.E. Spear, L.P. Spear, J.A. Mennella, M.J. Lewis, The international society for developmental psychobiology 39th annual meeting symposium: alcohol and development: beyond fetal alcohol syndrome, Dev. Psychobiol. 49 (2007) 227–242.
[2] N.E. Spear, J.C. Molina, Fetal or infantile exposure to ethanol promotes ethanol ingestion in adolescence and adulthood: a theoretical review, Alcohol.: Clin. Exp. Res. 29 (2005) 909–929.
[3] A.A. Bachmanov, S.W. Kiefer, J.C. Molina, M.G. Tordoff, V.B. Duffy, L.M. Bartoshuk, J.A. Mennella, Chemosensory factors influencing alcohol perception preferences, and consumption, Alcohol.: Clin. Exp. Res. 27 (2003) 220–231.
[4] G.K. Beauchamp, J.A. Mennella, Flavor perception in human infants: development and functional significance, Digestion 83 (2011) 1–6.
[5] A. Beckes, C. Larose, P. Gouat, J. Serra, Effect of pre and postnatal olfactogustatory experience on early preferences at birth and dietary selection at weaning in kittens, Chem. Senses 365 (2010) 41–45.
[6] P. Langendijk, J.E. Bolhuis, B.F.A. Laurenssen, Effects of pre and postnatal exposure to garlic and aniseed flavour on pre and postweaning feed intake in pigs, Livest. Sci. 108 (2007) 284–287.
[7] N. Sakai, The psychology of eating from the point of view of experimental, social, and applied psychology, Psychol. Russia: State Art 7 (2014) 14–22.
[8] S. Moriceau, R.M. Sullivan, Neurobiology of infant attachment, Dev. Psychobiol. 47 (2005) 230–242.
[9] J.A. Mennella, C.P. Jagnow, G.K. Beauchamp, Prenatal and postnatal flavor learning by human infants, Pediatrics 107 (2001) E88.
[10] G.V. Kamenetzky, A.B. Suárez, R.M. Pautassi, A.E. Mustaca, M.E. Nizhnikov, Change in the hedonic value of an aversive stimulus in the presence of a pre-exposed odor, Physiol. Behav. 148 (2015) 51–57.
[11] K.C. Berridge, Pleasures of the brain, Brain Cogn. 52 (2003) 106–128.
[12] P.M. Di Lorenzo, S.W. Kiefer, A.G. Rice, J. Garcia, Neural and behavioral responsivity to ethyl alcohol as tastant, Alcohol 3 (1986) 55–61.
[13] C. Arias, M.G. Chotro, Increased preference for ethanol in the infant rat after prenatal ethanol exposure, expressed on intake and taste reactivity tests, Alcohol.: Clin. Exp. Res. 29 (2005) 337–346.
[14] M.G. Chotro, J.C. Molina, Bradycardiac responses elicited by alcohol odor in rat neonates: influence of in utero experience with ethanol, Psychopharmacology (Berl.) 106 (1992) 491–496.
[15] A.E. Faas, S.M. March, P.R. Moya, J.C. Molina, Alcohol odor elicits appetitive facial expressions in human neonates prenatally exposed to the drug, Physiol. Behav. 148 (2015) 78–86.
[16] M.C. Fabio, S.M. March, J.C. Molina, M.E. Nizhnikov, N.E. Spear, R.M. Pautassi, Prenatal ethanol exposure increases ethanol intake and reduces C-fos expression in infralimbic cortex of adolescent rats, Pharmacol. Biochem. Behav. 103 (2013) 842–852.
[17] J.H. Hannigan, L.M. Chiodo, R.J. Sokol, J. Janisse, V. Delaney-Black, Prenatal alcohol exposure selectively enhances young adult perceived pleasantness of alcohol odors, Physiol. Behav. 148 (2015) 71–77.
[18] H.D. Domínguez, M.F. López, J.C. Molina, Neonatal responsiveness to alcohol odor and infant alcohol intake as a function of alcohol experience during late gestation, Alcohol 16 (1998) 109–117.
[19] R.M. Pautassi, M.E. Nizhnikov, N.E. Spear, Assessing appetitive, aversive, and negative ethanol-mediated reinforcement through an immature rat model, Neurosci. Biobehav. Rev. 33 (2009) 953–974.
[20] P.G. Hepper, Adaptive fetal learning: prenatal exposure to garlic affects postnatal preferences, Anim. Behav. 35 (1988) 1343–1346.
[21] S. Nicholaides, O. Galaverna, C.H. Meltzer, Extracellular dehydration during pregnancy increases salt appetite of offspring, Am. J. Physiol. 258 (1990) 281–283.
[22] W.P. Smotherman, In utero chemosensory experience alters taste preferences and corticosterone responsiveness, Behav. Neural Biol. 36 (1982) 61–68.
[23] G. Stickrod, D.P. Kimble, W. Smotherman, In utero taste/odor aversion conditioning in the rat, Physiol. Behav. 28 (1982) 5–7.
[24] E.S. Petrov, E.I. Varlinskaya, W.P. Smotherman, The newborn rat ingests fluids

through a surrogate nipple: a new technique for the study of early suckling behavior, Physiol. Behav. 62 (1997) 1155–1158.
[25] S.S. Miller, N.E. Spear, Olfactory learning in the rat neonate soon after birth, Dev. Psychobiol. 50 (2008) 554–565.
[26] S.S. Miller, N.E. Spear, Olfactory learning in the rat immediately after birth: unique salience of first odors, Dev. Psychobiol. 51 (2009) 488–504.
[27] S.S. Miller, N.E. Spear, Mere odor exposure learning in the rat neonate immediately after birth and 1 day later, Dev. Psychobiol. 52 (2010) 343–351.
[28] R.M. Sullivan, Developing a sense of safety, in: J. King, C. Ferris, I. Lederhendler (Eds.), Neurobiology of Neonatal Attachment, Roots of Mental Illness in Children, CDAD, 2003, pp. 122–132.
[29] K.J. Upton, R.M. Sullivan, Defining age limits of the sensitive period for attachment, Dev. Psychobiol. 52 (2003) 453–464.
[30] S. Levine, Primary social relationships influence the development of the hypothalamic pituitary adrenal axis in the rat, Physiol. Behav. 73 (2001) 255–260.
[31] B. Schaall, L. Marlier, R. Soussignan, Human fetuses learn odours from their pregnant mother's diet, Chem. Senses 25 (2000) 729–737.
[32] P.E. Simitzis, S.G. Deligeorgis, J.K. Bizelis, K. Fegeros, Feeding preferences in lambs influenced by prenatal flavour exposure, Physiol. Behav. 93 (2008) 529–536.
[33] D.L. Wells, P.G. Hepper, Prenatal olfactory learning in the domestic dog, Anim. Behav. 72 (2006) 681–686.
[34] C. Raineki, S. Moriceau, R.M. Sullivan, Developing a neurobehavioral animal model of infant attachment to an abusive caregiver, Biol. Psychiatry 67 (2010) 1137–1145.