IV. Gehirne afrikanischer Insektivoren. Versuch einer Zuordnung von Hirnbau und Lebensweise. Morph. Jb. **103**, 108–174.
WALKER, E. P. (1964): Mammals of the world. Vol. II. Baltimore: Johns Hopkins Press.
WEBER, M. (1896): Vorstudien über das Hirngewicht der Säugethiere. Festschrift f. Gegenbaur **3**, 105–123.
WELCKER, H.; BRANDT, A. (1903): Gewichtswerthe der Körperorgane bei dem Menschen und den Thieren. Arch. Anthropol. **28**, 1–89.

Authors' addresses: Dr. HEINZ STEPHAN, Max-Planck-Institut für Hirnforschung, Neurobiologische Abt., Deutschordenstr. 46, D-6000 Frankfurt/Main 71; Dr. FRITZ DIETERLEN, Staatliches Museum für Naturkunde, Schloß Rosenstein, D-7000 Stuttgart

The influence of the sexual cycle on the olfactory sensitivity of wild female house mice *(Mus musculus domesticus)*

By M. RITTNER and U. SCHMIDT

Zoological Institute, University of Bonn

Receipt of Ms. 10. 8. 1981

Abstract

Studied was the influence of the sexual cycle of the olfactory sensitivity of wild female house mice *(Mus musculus domesticus)*, using a two-choice training apparatus. Large fluctuations in olfactory sensitivity related to the sexual cycle were shown with the odourant geraniol ($C_{10}H_{17}OH$). During proestrus the mice recognized a concentration of 5×10^8 molecules geraniol/cm^3 air, while in metestrus they did not even respond to a concentration of 5×10^{11} molecules/cm^3.

Introduction

The sense of smell plays a major role in social behaviour of house mice. For example, the sexual cycle of female mice may be accelerated when exposed to a male odour (WHITTEN 1958). Olfactory contact with strange males can even lead to a depression of gravidity (BRUCE 1959, 1962; DOMINIC 1966).

While olfactory sensitivity in males is constant over a long period of time, the females' varies in relation to the sexual cycle (SCHMIDT 1979). The results from these electrophysiological experiments and behavioral studies with rats (PIETRAS and MOULTON; PHILLIPS 1974 and VALLOWE 1975) differ greatly. Thus, studies with trained wild mice need to be conducted to determine wheater these differences are a result of methods employed.

Material and methods

Nine female mice, approximately four months old, whose parents were caught in the wild, were used in this experiment. A two-choice training apparatus consisting of transparent plexiglass half-tubes was used. The gaseous odour was pumped via a nozzle into one of the tunnels, while filtered air entered the other tube. The location of the olfactory stimulus was randomly distributed. Three experimental animals were trained to reject the odour while the other six were trained to choose the olfactory marked side. The animals were punished with an electric shock each time they responded incorrectly. Each correct response was rewarded with food (for details of this method, see SCHMIDT 1979). Vaginal smears were done every day after the mice completed 30 trials in order to determine the stage of the sexual cycle of each mouse (ALLEN 1922; ZONDECK and ASCHHEIM 1926).

U.S. Copyright Clearance Center Code Statement: 0044-3468/82/4701-0047 $ 02.50/0
Z. Säugetierkunde 47 (1982) 47–50

ISSN 0044-3468 / InterCode: ZSAEA 7

The training odour used was geraniol ($C_{10}H_{17}OH$), a flowery smelling scent found in a number of flower oils. Even in high concentrations this essence has no damaging effects.

Because extremely high concentrations of geraniol were rejected by all mice, the only reliable results were achieved with mice trained to avoid the olfactory stimulus. Therefore only the data of these three mice were analysed.

Results

For pretraining a geraniol concentration of 10^{13} molecules geraniol/cm^3 air was used. To determine the threshold the concentration was reduced by the factor 10 from 5×10^{11} to 5×10^{7} molecules geraniol/cm^3 air (each concentration level was maintained seven days). The reduced odour intensity was only applied during runs 1–20 (the first four trials were not included in the analysis). The last ten runs were done at the highest level of concentration (10^{13} molecules/cm^3). These ten runs served as a control and to retrain the animals.

The influence of the sexual cycle on the percentage of correct choices could already be observed at a concentration of 5×10^{11} molecules geraniol/cm^3 air. 80–100 % correct responses were recorded during proestrus, while only 50–70 % correct responses were achieved during the metestrus. Responses made during estrus and diestrus lie between these two extremes. The correct responses in diestrus, proestrus and estrus were statistically significant (t-test, $p < 0.01$) up to a concentration of 5×10^{8} molecules geraniol/cm^3 air. Test animals in all stages of their cycles no longer reacted to the essence when concentration reached 5×10^{7} molecules geraniol/cm^3 air. Figure 1 illustrates the per cent of positive responses of the three animals in all four cyclic stages.

Proestrus is significantly different (z-test, $p < 0.01$) from the other three stages; estrus and diestrus can also be differentiated from metestrus. The daily control- and retraining-runs at a geraniol concentration of 2 volume % ($\triangleq 10^{13}$ molecules geraniol/cm^3 air) showed only little fluctuation and kept within the highly significant positive response level. This indicates that the differences in olfactory capacity were not due to chance and were not a result of training insecurity (fig. 2).

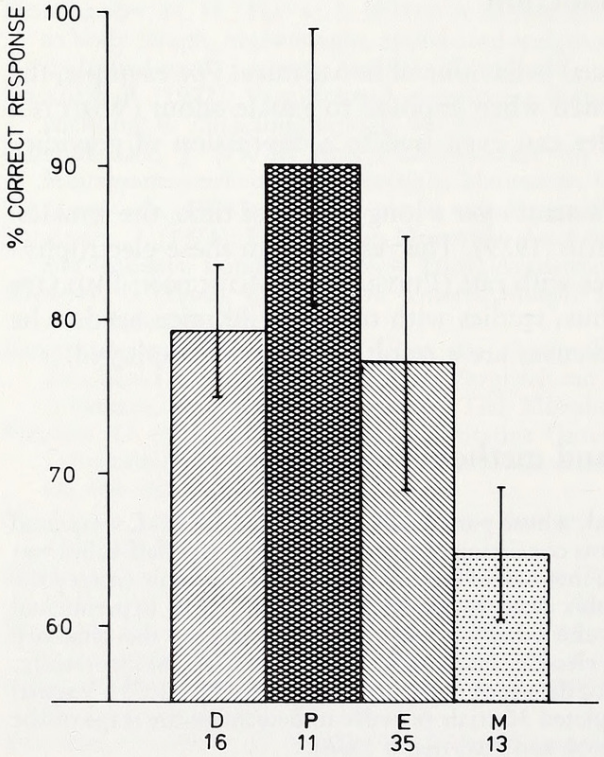

Fig. 1. Percentage of correct responses of the three test animals during diestrus (D), proestrus (P), estrus (E) and metestrus (M) at all above threshold concentrations of geraniol. The vertical bars indicate the standard deviation, the numbers under the colums the number of the days investigated

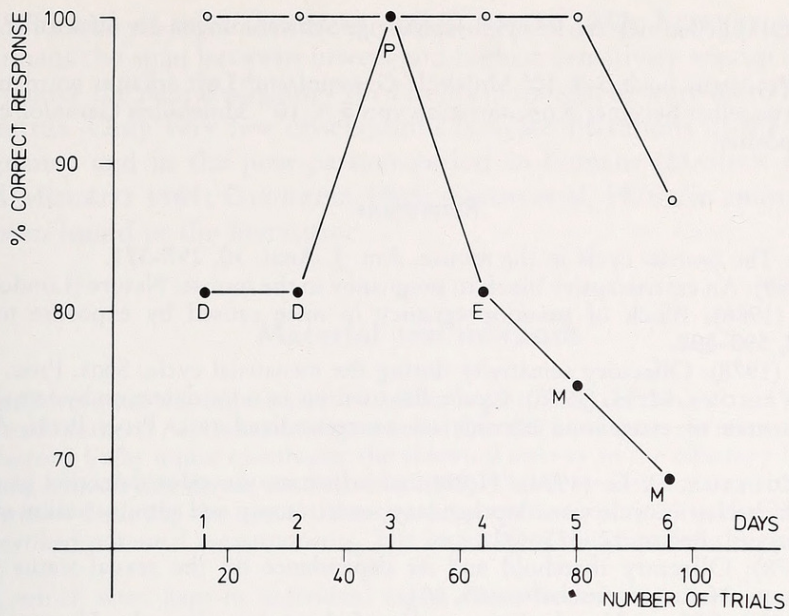

Fig. 2. Training performance of a female house mouse during six consecutive days at an odour concentration of 5×10^8 molecules geraniol/cm^3 air – (filled circles) and at retraining with 5×10^{13} molecules geraniol/cm^3 air – (open circles). D = diestrus; P = proestrus; E = estrus; M = metestrus

Discussion

The results of this investigation correspond with those of C. SCHMIDT (1978, 1979) in which electrophysiological methods were used to examine the olfactory capacity of white laboratory mice. The odour substances used in SCHMIDT's experiment were geraniol, butyric acid and butyric methyl ester. In all three test substances the typical fluctuations in olfactory ability were observed, indicating that these variations are independent of the odour offered. Neural thresholds also showed a maximal olfactory sensitivity in proestrus.

Experiments studying olfactory sensitivity in female rats (PIETRAS and MOULTON 1974; PHILLIPS and VALLOWE 1975; MOULTON 1978) showed the highest sensitivity in the estrus stage and a minimum of olfactory performance in metestrus and diestrus. Although these differences between mice and rats may be due to variations within these two species, it most probably was caused by the different methods of training used in each experiment. Each rat did ten trial runs per day at a medium odour concentration. Due to the relatively few runs, the performance level may have changed during sexual cycle. The security of response decreased during metestrus because of a decline in olfactory ability. During diestrus and proestrus the animals might have successfully relearned the problem – which lead to a maximal surety of training in the following estrus. The continual pattern of training and detraining could be eliminated from present investigation through daily training with a high odour concentration so that the response level remained consistent.

Cyclic fluctuations in olfactory sensitivity which are expressed on the peripheral level as well as in perceptual level has not yet been attributable to any biological function. Behavioral studies need to be done to show whether female mice have gained an evolutionary advantage through it.

Zusammenfassung

Die Beeinflussung des Riechvermögens durch den Sexualzyklus bei weiblichen Hausmäusen (Mus musculus domesticus)

Bei wilden ♀♀ Hausmäusen *(Mus musculus domesticus)* wurde mit Hilfe einer Zweifach-Wahl-Dressur die Beeinflussung des Riechvermögens durch den Sexualzyklus untersucht. Für den Duftstoff

Geraniol ($C_{10}H_{17}OH$) ließen sich starke zyklusabhängige Schwankungen der olfaktorischen Sensitivität nachweisen.

Während im Proöstrus noch 5×10^8 Moleküle Geraniol/cm³ Luft erkannt wurden, wählten die Mäuse im Metöstrus selbst bei einer Konzentration von 5×10^{11} Molekülen Geraniol/cm³ Luft nicht mehr signifikant positiv.

References

Allen, E. (1922): The oestrus cycle in the mouse. Am. J. Anat. **30**, 297–371.

Bruce, H. M. (1959): An exteroceptive block to pregnancy in the mouse. Nature (London) **184**, 105.

Dominic, C. J. (1966): Block of pseudopregnancy in mice caused by exposure to male urine. Experientia **22**, 590–598.

Moulton, T. H. (1978): Olfactory sensitivity during the menstrual cycle. Sens. Proc. **2**, 90–98.

Phillips, P. D.; Vallowe, H. H. (1975): Cyclic fluctuations in odor detection by female rats and the temporal influences of exogenous steroids on ovarectomized rats. Proc. Penn. Acad. Sci. **49**, 160–164.

Pietras, R. J.; Moulton, D. G. (1974): Hormonal influences on odor detection in rats: Changes associated with the estrus cycle, pseudopregnancy, ovariectomy and administration of testosterone propionate. Physiol. Behav. **12**, 475–491.

Schmidt, C. (1978): Olfactory threshold and its dependence on the sexual status in the female laboratory mouse. Naturwissenschaften **65**, 601.

Schmidt, C. (1979): Elektrophysiologische und verhaltensphysiologische Untersuchungen zum Riechvermögen der weißen Labormaus *(Mus musculus)*. Diss. Bonn.

Whitten, W. K. (1958): Modification of the oestrus cycle of the mouse by external stimuli associated with the male. Changes in the oestrus cycle determined by vaginal smears. J. Endocrinol. **17**, 307–313.

Zondeck, B.; Aschheim, S. (1926): Der Scheidenzyklus der weißen Maus als Testobjekt zum Nachweis des Ovarialhormons. Klin. Wschr. **22**, 979–985.

Authors' address: M. Rittner and Prof. Dr. U. Schmidt, Zoologisches Institut der Universität, Poppelsdorfer Schloß, D-5300 Bonn

Olfaction in pregnant and lactating albino mice

By Christel Schmidt and U. Schmidt[1]

Zoological Institute, University of Bonn

Receipt of Ms. 2. 10. 1981

Abstract

Studied were the alterations of the neural olfactory threshold during pregnancy and lactation in albino mice (NMRI-strain) by means of evoked potential measurements from the Bulbus olfactorius. After copulation the threshold to geraniol is raised from the low proestrus level to a medium level that remains stable during most of the gestation period. Two to three days before parturition the olfactory acuity increases, till immediately after giving birth a sensitivity peak is reached. In the presence of a male this hyperosmia lasts a maximum of 4 days, in isolated females up to 8 days. The biological significance of this effect is discussed.

Introduction

During the sexual cycle of females, the olfactory sensitivity changes to a very high degree. This has been found in humans (Le Magnen 1952; Köster 1965; Vierling and Rock 1967; Doty et al. 1981), as well as in rats (Pietras and Moulton 1974; Phillips and

[1] The authors thank the Deutsche Forschungsgemeinschaft for financial support.

U.S. Copyright Clearance Center Code Statement: 0044-3468/82/4701-0050 $ 02.50/0
Z. Säugetierkunde 47 (1982) 50–55

ISSN 0044-3468 / InterCode: ZSAEA 7