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Letter to the Editor

Comments to K.E. Wynne-Edwards and M.E. Timonin 2007. Paternal care in rodents: Weakening support of hormonal regulation of the transition to behavioral fatherhood in rodent animal models of biparental care, Horm & Behav 52: 114–121

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In an earlier issue of Hormones and Behavior, Wynne-Edwards and Timonin reviewed more than one decade of studies on the endocrinology of paternal care in male rodents (Wynne-Edwards and Timonin, 2007). While most studies demonstrated correlations between being a father and hormone levels, especially Wynne-Edwards and co-workers also conducted important experiments during the last years to test for a causal relationship. However, the conclusions of Wynne-Edwards and Timonin are rather negative: (1) "The co-variation between hormones and paternal care is not causal" (abstract); (2) "The hypothesis of homology between maternal and paternal neuroendocrine circuits is false" (p. 120).

Here I want to argue that these conclusions are too early, and that more detailed and especially more complex studies are needed. In addition, I think that the following important question has to be approached: "Why do rodent fathers show changes in hormone levels?".

The co-variation between hormones and paternal care is not causal

As reviewed by Wynne-Edwards and Timonin, paternal rodent males typically show a decrease in testosterone levels and an increase of prolactin levels, while other hormones do not change noticeably or in a species specific manner. This suggests that high testosterone levels might suppress paternal care, as it occurs in many bird species (Beletsky et al., 1995; Wingfield et al., 1990), and increased prolactin levels could promote paternal care, as in several fish and bird species (Schradin and Anzenberger, 1999; Ziegler, 2000). However, castration of naive males of the highly paternal dwarf hamster *Phodopus campbelli* does not influence later paternal responsiveness nor is testosterone reduced in fathers of all paternal species (Wynne-Edwards and Timonin, 2007). In addition, experimental reduction of prolactin levels in fathers of the dwarf hamster *P. campbelli* did not lead to a reduced level of retrieval of pups into the nest (Brooks et al., 2005).

Wynne-Edwards and Timonin expected that changes in hormone levels could be the mechanism to change an infanticidal male to a caring father. However, males do not only switch from infanticide to being paternal, but might also switch from searching for additional mates to being associated for a long time to one female and her offspring. Two different mechanisms might exists, one to switch from mate searching to staying with one female at her nest, another one to switch from infanticide to paternal care. In house mice, a series of experimental studies have demonstrated that the switch from infanticide to being paternal seems to be a neural mechanism, not an endocrine one (Perrigo et al., 1991; Soroker and Terkel, 1988). Mating induces in males a change, with infanticide being switched off around the expected date of parturition (Huck et al., 1982; Mennella and Moltz, 1988; Saal and Howard, 1982). Therefore, if hormones play a role in the regulation of paternal care, this is unlikely to be the change

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from infanticide to being paternal. Rather, hormones might be important for the fine tuning, which is how much paternal care is shown. Paternal care in rodents is costly in the currency of time, e.g. striped mouse males increasing the time spent in the nest by a factor of three when pups are present (Schradin and Pillay, 2003). Thus, the amount of paternal care shown might be a trade-off with other activities such as foraging and especially searching for additional receptive females, either by roaming over several female territories or by searching for encounters with neighboring females. However, laboratory experiments typically do not mimic this natural situation. In contrast, males are put in a relatively small cage (e.g. 0.000025 ha in captivity compared to 0.1 to 1.0 ha in a natural population of striped mice, Schradin and Pillay, 2003, 2005) without any need for foraging (food provided ad libitum) and no potential to search for additional females. Typically, in captive experiments, non-infanticidal males are in a small cage and have no other option than to show paternal care, as there is no need for foraging and no possibility to search for mates. The only other option would be to do nothing, but if we compare between males with high paternal motivation (maybe males with high prolactin levels) and males with medium paternal motivation (maybe males with experimentally reduced prolactin levels), both classes might choose paternal care. Therefore, laboratory studies mimicking a much more complex situation would be necessary, e.g. by providing males the opportunity to visit additional females.

The hypothesis of homology between maternal and paternal neuro-endocrine circuits is false

A series of experiments since the 1970s have demonstrated that the rapid onset of maternal care in the rat depends on the hormones progesterone, estrogen and prolactin which change during pregnancy (Bridges et al., 1985, 1978; Bridges and Mann, 1994; Bridges and Ronsheim, 1990; Rosenblatt, 1992). This is why the endocrine regulation of maternal care in the rat has been regarded as a model to understand the physiological regulation of parental care in mammals in general, including the regulation of male parental care in rodents (Schradin and Anzenberger, 1999; Wynne-Edwards, 2001). Clearly, the results of the experiments with decreased prolactin (Brooks et al., 2005) and estradiol (Hume and Wynne-Edwards, 2006) levels described by Wynne-Edwards and Timonin demonstrate that this is not the case in hamsters of the genus *Phodopus*.

Wynne-Edwards and Timonin conclude that the hypothesis that paternal care will activate pre-existing maternal endocrine pathways was supported by correlative data (changes in hormone levels), but not by experiments trying to demonstrate a causal relationship. This conclusion is correct, but only for the endocrine pathways of rodent first time mothers. Experienced rat females experience similar hormonal changes as first time mothers, but do not need endocrine changes to respond maternally (Bridges, 1978, 1975). The proximate mechanisms of maternal care in experienced females are not well understood, nor are the proximate mechanisms of paternal care. Therefore, it is possible that the neuro-endocrine basis of paternal care is similar to the one of maternal care in experienced mothers.

While first-time mothers can rely totally on the endocrine signals of pregnancy to know whether it will be necessary to show maternal care, the endocrine changes in rodent males are a less reliable signal. Both in experienced mothers and fathers, experience and social stimuli (leading to physiological changes, possibly directly activating neural circuits) might be more important than in first-time mothers, which rely mainly on the hormones of pregnancy. Therefore, if one signal (e.g. prolactin) does not occur, it might still be beneficial for a male to respond paternally. In fact, a male should rely on several signals (endocrine and environmental ones). “Although the indications of a relationship between prolactin and paternal care are overwhelming, it is clear that prolactin cannot be the only factor…. It is extremely unlikely that paternal care would depend on a single factor only, as this would render it highly susceptible to defects. Life-sustaining processes generally depend on numerous factors as a kind of insurance, so that they will continue to operate, albeit at reduced level, after the breakdown of one factor.” (cited from Schradin and Anzenberger, 1999). If this is true, then the effect of the experimental decrease of prolactin in parental rodent fathers can be expected to be not as strong as in first-time rodent mothers, and much larger sample sizes might be needed.

Why do paternal rodent fathers show the observed changes in hormone levels?

Wynne-Edwards and Timonin argue that the hormonal changes observed in paternal male rodents might be important for other behaviors such as postpartum mating. However, they neither explain why post-partum mating might depend on increased prolactin levels (a hormone known for its fertility reducing effect in many species), nor why there should be a difference between paternal and non-paternal species. Hormonal changes observed in paternal but not in non-paternal species are most parsimoniously explained by differences in care giving behavior. If further experiments support the results of the experiments done by Wynne-Edwards and co-workers that paternal behavior is not influenced by the associated endocrine changes, one has to ask in what other aspects than behavior do paternal males differ from non-paternal males. This would be an extremely interesting and promising field of research. One possibility could be that energy budgets differ and that this is regulated hormonally. Apart from differences in metabolism, differences in osmo-regulation are possible.

Conclusions

In conclusion, more experiments on more species are needed. These experiments must mimic a more complex environment, especially giving males the option to do something else than to show paternal care. As one single hormone might have a rather small influence, large sample sizes are needed. Furthermore, the many environmental variables that can influence maternal and paternal care (Brown, 1993) must be considered, and in how far

there might be differences between the sexes in the quality and quantity of physiological responses to these environmental stimuli (Schradin, 2002, 2007). Other differences between paternal and non-paternal males must also be considered, especially differences in metabolism and osmo-regulation that could be controlled hormonally. Thus, while we cannot expect a single hormone to transform an infanticidal male into a caring father, modulation effects of hormones on paternal care are still an interesting topic of research.

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References

Beletsky, L.D., Gori, D.F., Freeman, S., Wingfield, J.C., 1995. Testosterone and polygyny in birds. In: Power, D.M. (Ed.), Current Ornithology. Plenum, New York, pp. 1–41.

Bridges, R.S., 1975. Long-term effects of pregnancy and parturition upon maternal responsiveness in the rat. Physiol. Behav. 14, 245–249.

Bridges, R.S., 1978. Retention of rapid onset of maternal behavior during pregnancy in primiparous rats. Behav. Biol. 24, 113–117.

Bridges, R.S., Mann, P.E., 1994. Prolactin-brain interactions in the induction of maternal behavior in rats. Psychoneuroendocrinology 19, 611–622.

Bridges, R.S., Ronsheim, P.M., 1990. Prolactin (PRL) regulation of maternal behavior in rats: bromocriptine treatment delays and PRL promotes the rapid onset of behavior. Endocrinology 126, 837–848.

Bridges, R.S., Rosenblatt, J.S., Feder, H.H., 1978. Serum progesterone concentrations and maternal behavior in rats after pregnancy termination: behavioral stimulation after progesterone withdrawal and inhibition by progesterone maintenance. Endocrinology 102, 258–267.

Bridges, R.S., Dibiase, R., Loundes, D.D., 1985. Prolactin stimulation of maternal behavior in female rats. Science 227, 782–784.

Brown, R.E., 1993. Hormonal and experiential factors influencing parental behaviour in male rodents: an integrative approach. Behav. Processes 30, 1–28.

Brooks, P.L., Vella, E.K., Wynne-Edwards, K.E., 2005. Dopamine agonist treatment before and after birth reduces prolactin concentration but does not impair paternal responsiveness in Djungarian hamsters, *Phodopus campbelli*. Horm. Behav. 47, 358–366.

Huck, U.W., Soltis, R.L., Coopersmith, C.B., 1982. Infanticide in male laboratory mice: effects of social status, prior sexual experience, and basis for discrimination between related and unrelated young. Anim. Behav. 30, 1158–1165.

Hume, J.M., Wynne-Edwards, K.E., 2006. Paternal responsiveness in biparental dwarf hamsters (*Phodopus campbelli*) does not require estradiol. Horm. Behav. 49, 538–544.

Mennella, J.A., Moltz, H., 1988. Infanticide in rats: male strategy and female counter-strategy. Physiol. Behav. 42, 19–28.

Perrigo, G., Belvin, L., v. Saal, F.S., 1991. Individual variation in the neural timing of infanticide in male house mice. Physiol. Behav. 50, 287–296.

Rosenblatt, J.S., 1992. Hormone-behavior relations in the regulation of parental behavior. In: Becker, J.B., Breedlove, S.M., Crews, D. (Eds.), Behavioral Endocrinology. MIT Press, Cambridge, pp. 219–259.

Saal, F.S., Howard, L.S., 1982. The regulation of infanticide and parental behavior: implications for reproductive success in male mice. Science 215, 1270–1272.

Schradin, C., 2002. Die vier Fragen Tinbergens und väterliches Verhalten. In: Ganslosser, U. (Ed.), Gruppenmechanismen. Filander, Fürth, pp. 29–47.

Schradin, C., 2007. Die Biologie des Vaters. Filander, Fürth.

Schradin, C., Anzenberger, G., 1999. Prolactin, the hormone of paternity. News Physiol. Sci. 14, 223–231.

Schradin, C., Pillay, N., 2003. Paternal care in the social and diurnal striped mouse (*Rhabdomys pumilio*): laboratory and field evidence. J. Comp. Psychol. 117, 317–324.

Schradin, C., Pillay, N., 2005. Intraspecific variation in the spatial and social organization of the African striped mouse. J. Mammal. 86, 99–107.

Soroker, V., Terkel, J., 1988. Changes in incidence of infanticidal and parental response during the reproductive cycle in male and female wild mice *Mus musculus*. Anim. Behav. 36, 1275–1281.

Wingfield, J.C., Hegner, R.E., Dufty, A.M., Ball, G.F., 1990. The "challenge hypothesis": theoretical implications for patterns of testosterone secretion, mating systems, and breeding strategies. Am. Nat. 163 (6), 829–846.

Wynne-Edwards, K.E., 2001. Hormonal changes in mammalian fathers. Horm. Behav. 40, 139–145.

Wynne-Edwards, K.E., Timonin, M.E., 2007. Paternal care in rodents: weakening support for hormonal regulation of the transition to behavior fatherhood in rodent animal models of biparental care. Horm. Behav. 52, 114–121.

Ziegler, T.E., 2000. Hormones associated with non-maternal infant care: a review of mammalian and avian studies. Folia Primatol. 71, 6–21.