Pharmacology, Biochemistry and Behavior 121 (2014) 43–52

Contents lists available at ScienceDirect

Pharmacology, Biochemistry and Behavior

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

Serotonin 1A receptors and sexual behavior in female rats: A review

Eelke M.S. Snoeren [a,*], Jan G. Veening [b,c], Berend Olivier [b], Ronald S. Oosting [b]

[a] Department of Psychology, University of Tromsø, Tromsø, Norway
[b] Division of Pharmacology, Utrecht Institute for Pharmaceutical Sciences and Rudolf Magnus Institute of Neuroscience, Utrecht University, Universiteitsweg 99, 3584CG Utrecht, The Netherlands
[c] Department of Anatomy, Radboud University Nijmegen Medical Center, Nijmegen, The Netherlands

ARTICLE INFO

Available online 22 November 2013

Keywords:
Serotonin
5-HT_{1A} receptors
Sexual behavior
Female
Animal models

ABSTRACT

This review focuses on the role of serotonin and especially 5-HT_{1A} receptors in female rat sexual behavior. In addition, the differences and/or similarities with male rats are discussed. Overall, in both males and females 5-HT_{1A} receptors do not appear to be involved in sexual behavior under normal circumstances, but become very important under conditions of elevated serotonin levels. 5-HT_{1A} receptor agonists facilitate sexual behavior in male rats, but inhibit female sexual activity. At first sight, this seems quite conflicting, but could be due to our definitions of different elements of sexual behavior. Three different phases can be distinguished in rats' sexual cycle, the introductory (precopulatory), the copulatory and the executive (ejaculatory) phases. Different mechanisms and brain regions are involved in these phases. If the appropriate phases of males and females are properly compared, the role of 5-HT_{1A} receptors in rats might be more similar than assumed thus far.

1. Introduction

Rat sexual behavior is an interaction between males and females in which the animals show several kinds of behaviors to influence each other and achieve sexual excitement. Basically, these behaviors form a cycle that can be divided into three phases: the introductory (precopulatory), copulatory, and the executive phases (in males ejaculations, in female rats unknown). The interplay between males and females starts with behaviors like approaching and sniffing each other's anogenital regions to obtain pheromonal cues of sexual receptivity. This introductory phase is followed by the copulatory phase in which female rats in estrus display a variety of complex solicitation, or proceptive behaviors; e.g. hopping, darting and ear wiggling. Hopping can be described as a kind of jumping behavior of the female with four legs off the ground, while darting is a runaway behavior with a sudden stop in which the female presents her body to the male rat for mounting. Ear wiggling, on the other hand, is a fast shaking movement with the head which can be recognized by the wiggling ears. The proceptive behaviors are species-typical and signal the readiness to mate, thereby functioning as an index of feminine sexual motivation (Beach, 1976). The copulatory phase for male rats consists of repeated intromissions and mounts. Intromissions are characterized as mounts including pelvic thrusting. In response to these copulatory behaviors, the females display lordosis or receptive behavior (also part of the copulatory phase) in which the female shows a hollow back and deflects her tail to one side allowing the male access to her vagina (Fig. 1). After a series of mounts and intromissions, ejaculation (the executive phase) is reached. In rats, usually 10 to 20 intromissions are needed during a short period (ca. 2–10 min) to reach an ejaculation. After an ejaculation a post ejaculatory interval (PEI) of about 5 min is started, which can be described as the resting period preceding the next ejaculation cycle (Fig. 2).

In addition to the mentioned behaviors, "pacing" is also important in female sexual behavior. This is the ability of the female rat to control the timing of the receipt of sexual stimulation, as a pattern of approach and withdrawal from the male. The female rat can decide to approach the male and start copulation or escape to a "safe" place where the male cannot reach her (this will only be seen in experimental environments with escape possibilities). The display of this behavior is directly dependent upon the intensity of the coital stimulation (mounts, intromissions and ejaculations) received immediately prior to the solicitation behaviors. The rate of approaches toward the male is negatively correlated with the intensity of the stimulus from the male (Erskine, 1985). During mating, the intermittent display of solicitation behaviors directly determines the type and timing of copulatory stimulation that the female receives. It has been reported that 90% of intromissions were preceded by approach/runaway solicitations by the female, while only 3% of intromissions were generated when the male approached the female (McClintock, 1978). The strong correlation between the amount of darts and male sexual behavior (mounts, intromissions and

Abbreviations: BNST, bed nucleus of the stria terminalis; BNSTpm, posteromedial part of bed nucleus of the stria terminalis; CTF, central tegmental field; DRN, dorsal raphé nucleus; EB, estrogen; Fos-IR, Fos-immunoreactivity; LQ, lordosis quotient; MeA, medial amygdala; MeApd, posterodorsal part of the medial amygdala; MGC, midbrain central gray; mPFC, medial prefrontal cortex; MPN, medial preoptic nucleus; MPOA, medial preoptic area; MRN, median raphé nucleus; NAc, nucleus accumbens; P, progesterone; PAG, periaqueductal gray; PD, posterodorsal preoptic nucleus; PEI, post ejaculatory interval; PMV, ventral premammillary nucleus; SERT, serotonin transporter; SPFp, subparafascicular nucleus; SSRI, selective serotonin reuptake inhibitor; VMN, ventromedial nucleus; VMNcv, caudoventral part of the ventromedial nucleus; VMNvl, ventrolateral part of the ventromedial nucleus.

* Corresponding author at: University of Tromsø, Department of Psychology, Huginbakken 32, 9038 Tromsø, Norway. Tel.: +47 77649215.
E-mail address: eelke.snoeren@uit.no (E.M.S. Snoeren).

0091-3057/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.pbb.2013.11.017

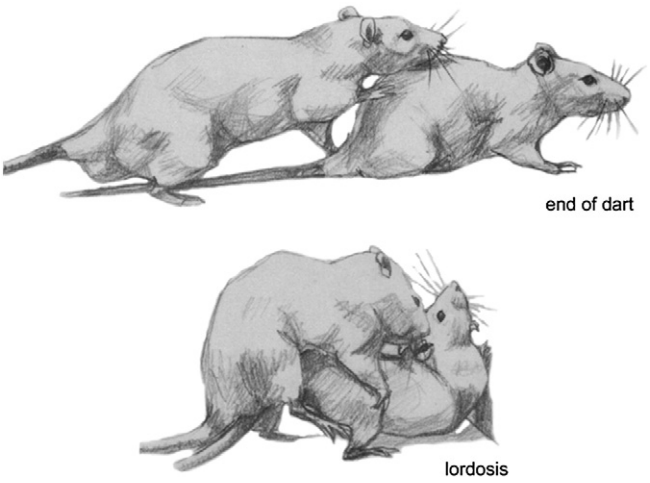

Fig. 1. Sexual behavior in female rats: dart and lordosis are shown in drawings by P.J.A. Timmermans. dart = a run through the cage with a sudden stop and the hind body down to allow the male to mount, lordosis = an arched back and deflection of her tail to one side allowing the male access to her vagina. Movie of all behaviors can be found on http://www.youtube.com/watch?v=H0gcqAlb9wI.

ejaculations) was also shown in Snoeren et al. (2011a). It has been shown that only paced mating, in contrast to nonpaced-mating is rewarding for female rats (Jenkins and Becker, 2003; Paredes and Alonso, 1997; Paredes and Vazquez, 1999). Sexual reward is essential for sexual functioning and should also be taken into account. However, this review focuses on the sexual behaviors itself and does, therefore, not discuss sexual reward further.

In animal research, several behavioral measurements are used as parameters for female and male sexual behavior. For the females, receptive behavior (part of the copulatory phase) is represented by lordosis behavior, which can be quantified by using lordosis quotient or lordosis score. The lordosis quotient is the percentage of time the female exhibited lordosis in response to a sexual contact with the male rat. The lordosis score is the intensity of the lordosis responses (Fig. 3), scored on a 4-point scale (0–3; (Hardy and Debold, 1971)). Solicitation behavior is measured by the amount of hops and darts female rats perform in the presence of a sexually active male rat. Measurements of paced mating capacity are contact-return latencies and percentages of exits after stimuli. These measurements are related to copulatory behaviors and are, therefore, parameters for the copulatory phase. For males, the mount-, intromission- and ejaculation frequencies, latencies and the PEI are usually used as parameters to quantify male sexual behavior

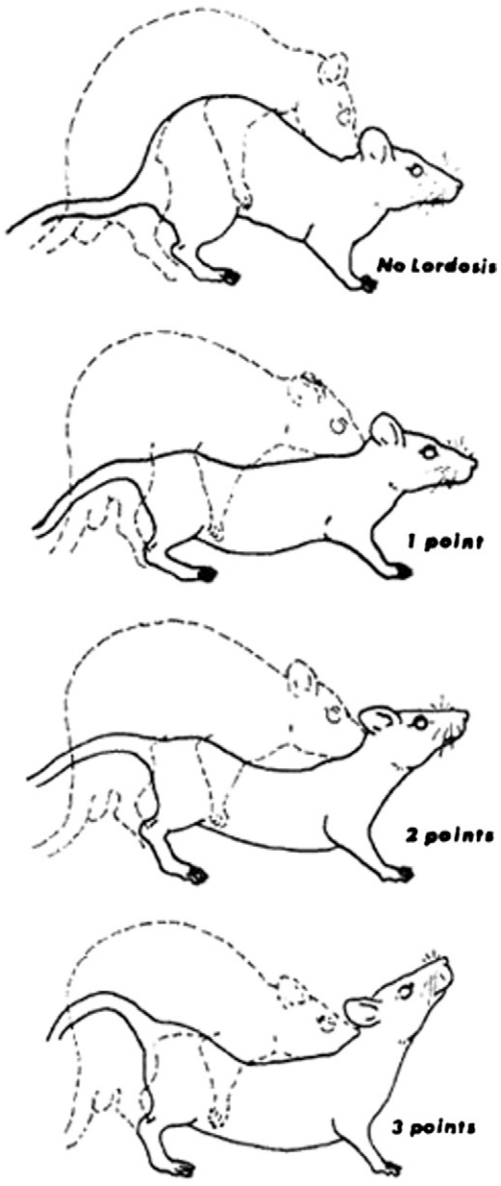

Fig. 3. Lordosis score is the intensity of the lordosis responses scored on a 4-point scale (0–3; (Hardy and Debold, 1971)).

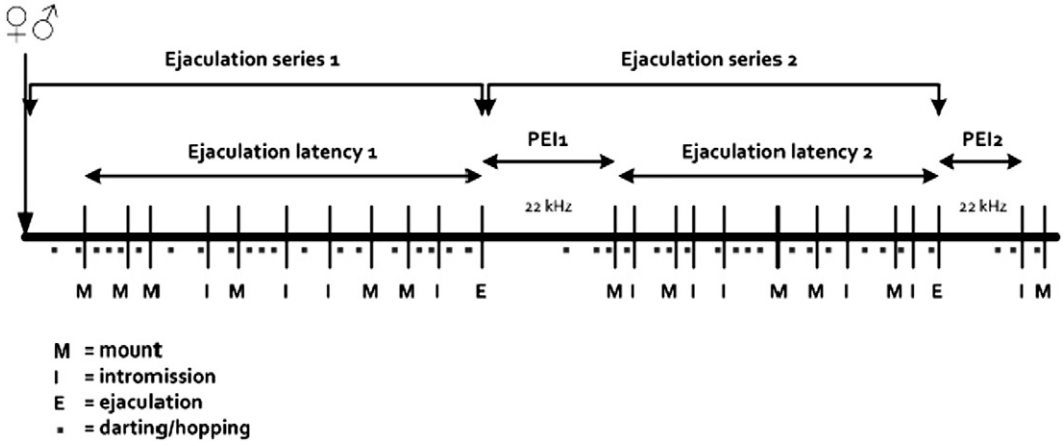

Fig. 2. Sexual response cycle of male and female sexual behaviors. There is a sequence of many ejaculations series within a 30 min period. Ejaculation latency is the time between the first male behavior and ejaculation within 1 series. PEL = post ejaculatory latency, which is the time to first male behavior after an ejaculation.