Medical Hypotheses 93 (2016) 122–125

Contents lists available at ScienceDirect

Medical Hypotheses

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

Sexual arousal and rhythmic synchronization: A possible effect of vasopressin

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ARTICLE INFO

Article history:
Received 26 April 2016
Accepted 26 May 2016

ABSTRACT

Music is ubiquitous. Yet, its biological relevance is still an ongoing debate. Supporting the view that music had an ancestral role in courtship displays, a pilot study presented here provides preliminary evidence on the link between music and sexual selection. The underlying hypothesis is based on the fact that the sexually dimorphic neuropeptide vasopressin has its receptors in the part of the brain involved in music and dance performance (the basal ganglia), and its concentrations rise during sexual arousal in men. In addition, music, dance, and courtship phenotypes seem to be in part regulated by vasopressin and its genes. Hence, to test this hypothesis, a rhythmic synchronization task was employed here on one male subject during sexual arousal. Results revealed a significant effect of sexual arousal on rhythm synchronization. This is the first report that empirically supports the hypothesis on the role of music in sexual selection. Further studies are clearly required.

Introduction

Whether or not music represents an evolutionary adaptation is still an active debate. For some, music is just a cheesecake that tickles our sensitive spots and could disappear leaving our species unchanged [1], while for others, music had an ancestral role in courtship [2–6] and group cohesion [7–9]. Further hypotheses focused on the emotional power of music, and sought a link with mother-infant interactions [10–12]. In recent years, empirical evidence supported the hypothesis that music and dance might have fostered social cohesion and cooperation [13–15], highlighting its adaptive function. However, in regard to the role of music in courtship displays, the recorded experimental data was mostly attained by investigating female preferences for musicians over non musicians [16,17]. Hence, the connection between musical performance and sexual behavior is an unexplored field that needs to be tested experimentally.

Based on animal models, the music for courtship hypothesis suggests that courtship is a male affair and females have a role in the selection of a mating partner carrying certain traits considered advantageous for offspring's survival. Music is indeed a reliable indicator of cognitive and motor abilities; therefore, an index of good genes that provide good offspring. This is because making music costs energies and it demands such an amount of competence that it would be hard to fake by unfit and unhealthy individuals. A male who carries the musical trait has more reproductive success, and through sexual selection, he transmits these skills to the next generation. Such a mechanism leads to an increased sexual dimorphism because males are encouraged to develop certain traits in order to facilitate access to females, and so reproductive success.

Theories based on sexual differences in art and music have been criticized on the basis that they represent a gendered view [18] and because the reported numerical advantage of men in music ensembles [2] seems to be related to a cultural phenomenon rather than a biological one [19]. However, a body of endocrine, neuroanatomical, and behavioral evidence suggests a reminiscence of a division of labor [20]. Few studies investigated directly sexual differences in music cognition and performance. For instance, the brain responses to musical syntax involve different scalp organization according to sex [21,22], 17-year-old males are better than females in a simple thumb-tapping task [23], whereas women display an advantage at declarative memory concerning familiar melody [24], perhaps due to estrogen activity in the hippocampus.

Indeed, since hormonal distribution between sexes is different, reflecting distinct biological roles in relation to sexual reproduction and parental investment, also endocrine responses to music are sexually dimorphic. Such differences affect steroid hormones such as testosterone [25–27], estradiol [27], cortisol [28], and perhaps prolactin [29].

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http://dx.doi.org/10.1016/j.mehy.2016.05.030
0306-9877/

The hypothesis

Our minds and bodies are the byproducts of the mating strategies adopted by our ancestors [30,31]. The hypothesis presented here claims that music had an ancestral role in courtship and, as an evolutionary spandrel (see e.g. [32]), some mechanisms that link music to this reproductive function are still in action nowadays. Neuroendocrinology and neuroanatomy will support this hypothesis focusing on the neuropeptide vasopressin and its activity in the brain.

Evaluation of the hypothesis

Rhythm in the brain

Neuroimaging studies have shown that along with motor areas and the cerebellum, one core structure is associated with rhythm perception and production, namely the basal ganglia [33]. The basal ganglia is specially linked to beat perception and motor prediction during simple rhythms, and so, it might be responsible for detecting stable beat intervals [34]. Its functional connectivity with cortical motor areas (premotor cortex and supplementary motor area) is greater during perception of a metric rather than a nonmetric rhythm [35], and it seems to work optimally during beat continuation rather than beat finding (i.e., a change of rhythm) [36]. As such, the basal ganglia assumes an important role in the internal generation of the beat, since it is also recruited during processing of relative durations (vs. absolute durations, a task served by the cerebellum) [37]. Within the basal ganglia, the putamen shows a significant difference in activation between simple and complex rhythms as well as between metric and nonmetric rhythms. Thus, the putamen seems sensitive to the presence of a beat structure [34–36].

As expected, the putamen is recruited also during dance, and it shows higher activation while dancing on a regular and metric rhythm, compared to a non regular rhythm [38]. A comparison between dancers and non dancers showed an enhanced cortico-basal ganglia connectivity, in which the putamen was connected to motor cortical areas [39]. What is of interest is that being rich in sex steroid receptors, the putamen is larger in men compared to women [40]. This, consistent with animal models, suggests a connection between the phenotypes of dance and courtship also in humans [41,42]. Music-like and dance-like behaviors are indeed widely adopted as courtship displays in a variety of species [19,43] where vasopressin plays an essential role [44–49].

Vasopressin, courtship, and music

Music and dance are found in all cultures and presumably emerged—along with language—with *Homo sapiens*, due to a genetic mutation in the gene called FOXP2: a disruption in this gene is associated with rhythmic and language impairment [50,51]. Representing a convergent evolution of a trait shared with other species [52], FOXP2 contributes to the appearance of a specific ability that allows an individual to attain fine motor movements in response to an auditory input. In the brain, such a mechanism is provided by the functional coupling of auditory and motor systems interconnected by the basal ganglia [53,54]. Rodent models suggest that the synaptic plasticity of the basal ganglia is in part modulated by this gene [55]. Recent evidence shows also that other species carrying the FOXP2 gene are capable of rhythm entrainment [56,57], suggesting an underlying neural substrate and a deep genetic homology.

Music and dance not only demand higher cognitive and motor skills in order to finely attune to other individuals, but they are also deeply intertwined with the social realm. A recent study showed that oxytocin, a neuropeptide involved in social bonding, increased interpersonal synchronization in a tapping task [58]. Because also vasopressin has strong connections with sociality [59], spatial and social memory [60,61], as well as with higher cognitive functions such as memory and learning in humans and other mammals [62], a series of studies started to investigate the role of vasopressin also in human music and dance. Such a coalition has been reported in several studies: the gene responsible for vasopressin receptor, AVPR1a, was associated with the dance phenotype [63], musical short-term memory [64], musical skills [65], and lifelong active listening to music [66]. Similarly, intranasal administration of vasopressin increased musical short-term memory performances [67].

The basal ganglia and vasopressin

Vasopressin is a sexually dimorphic neuropeptide with higher concentrations in males [68,69]. Vasopressin receptors are found in the basal ganglia of male rodents [70–72] and some male monkeys [73], while in humans, intranasal administration of vasopressin increases activity in the basal ganglia of men but not women [74–77], suggesting perhaps a sexually dimorphic distribution of vasopressin receptors. In addition, one study reported that during sexual activity in men, vasopressin peaks in the arousal phase (tested with masturbation), while after orgasm it falls back to baseline values [78]. A number of studies have shown that sexual arousal corresponds to an increased activity of the basal ganglia comprising the globus pallidus, the putamen, and the caudate nucleus [79–82], perhaps due to a vasopressinergic activity.

A pilot study

Following an established experimental design [58,83], this pilot study attempted to explore the relationship between sexual arousal and rhythmic synchronization through a tapping task. It was hypothesized that a surge in vasopressin in the basal ganglia due to sexual arousal improves tapping synchronization.

Methods and results

A USB midi keyboard connected to a MacBook Pro running Logic Pro X was used for recording rhythmic synchronization. One male subject (age 32, right-handed) was instructed to tap with his dominant finger over a metronome for 11 different tempi (120 ± 5, 10, 15, 20, and 25 bpm). A number of 36 sessions were recorded in three conditions: pre- ($N = 11$), post-orgasm ($N = 11$), and control condition ($N = 14$). Pre- and post-orgasm conditions required self-manual penile stimulation until the sexual arousal was reached. Once aroused, the subject performed the pre-orgasm task. Then, finished the task, he continued the stimulation until ejaculation occurred. After 3 min of rest, he could perform the post-orgasm task. The control condition did not involve any kind of sexual stimulation. Inter-ejaculation time (i.e., hours of sexual abstinence), the duration of penile stimulation, and the time of the day were also recorded.

Data was imported into MATLAB. The onset of tapping was extracted and then subtracted to the onset of the metronome. The assumption was that lower values are indices of best performances. A t-test showed no differences between pre- and post-orgasm task ($t(3858) = 0.80$, $p = 0.42$), thus they were grouped into a single variable for analysis. A one-way ANOVA revealed a significant effect of sexual arousal on tapping performance ($F(1, 3750) = 79.40$, $p < 0.0001$). A t-test between conditions per each tempo showed better performances for the tempi between 105 and