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The human sexual response cycle: Brain imaging evidence linking sex to other pleasures

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ABSTRACT

Sexual behavior is critical to species survival, yet comparatively little is known about the neural mechanisms in the human brain. Here we systematically review the existing human brain imaging literature on sexual behavior and show that the functional neuroanatomy of sexual behavior is comparable to that involved in processing other rewarding stimuli. Sexual behavior clearly follows the established principles and phases for wanting, liking and satiety involved in the pleasure cycle of other rewards. The studies have uncovered the brain networks involved in sexual wanting or motivation/anticipation, as well as sexual liking or arousal/consummation, while there is very little data on sexual satiety or post-orgasmic refractory period. Human sexual behavior also interacts with other pleasures, most notably social interaction and high arousal states. We discuss the changes in the underlying brain networks supporting sexual behavior in the context of the pleasure cycle, the changes to this cycle over the individual's life-time and the interactions between them. Overall, it is clear from the data that the functional neuroanatomy of sex is very similar to that of other pleasures and that it is unlikely that there is anything special about the brain mechanisms and networks underlying sex.

Contents

Abbreviations: Amy, amygdala; pACC, anterior cingulate cortex, pregenual part; sACC, anterior cingulate cortex, subgenual part; ASL, arterial spin labelling; BOLD, blood oxygenation level dependent; Cb, cerebellum; Claus, claustrum; dlPFC, dorsolateral prefrontal cortex; dmPFC, dorsomedial prefrontal cortex; FO, frontal operculum; FBA/EBA, fusiform body area/extrastriate body area; HT, hypothalamus; IPC, intraparietal cortex; med-temp, medial temporal lobe; aMCC, middle cingulate cortex, anterior part; NAcc, nucleus accumbens; OFC, orbitofrontal cortex; PERT, post-ejaculatory (orgasmic) refractory period; MI, primary motor cortex; SI, primary somatosensory cortex; SPL, superior parietal lobule; vmPFC, ventral medial prefrontal cortex; VP, ventral pallidum; vPMC, ventral part of the premotor cortex; VS, ventral striatum; vlOT, ventrolateral occipitotemporal; VSS, visual sexual stimulation.

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1. Introduction

Sex is costly as a reproductive strategy, yet crucial for the survival of species (Hamilton, 1964a,b; Morran et al., 2011). Across species there is a great diversity of behaviors associated with reproduction, and while much is known about the sexual behavior of other animals, human sexual behavior has remained mostly elusive.

Yet, sex is one of the driving forces of the human mind, and no other behavior is capable of raising controversy quite like sex. Indeed, sexuality issues such as same-sex attraction or sexual abuse are notorious for causing marked distress and unhappiness. Still, most of us would be inclined to agree that engaging in sexual activity is a source of immense pleasure. Moreover, sexual health and the pleasure gained from it positively predict general health outcome (Jannini et al., 2009), suggesting that there is much to be gained from understanding the underlying principles in order to be able to augment, or at least maintain, a certain level of sexual functionality.

Such underlying principles of sexual behavior must adhere to the adage that "the brain is the master organ of sexual function" (McKenna, 1999) and the focus on this review is to identify and outline the fundamental brain mechanisms. It is not, however, trivial to conduct sex studies in neuroimaging scanners (see Box 1) and there are significant limitations associated with these techniques (see Box 2).

The evidence clearly reveals that while there are some differences between sexual and other behaviors, there are in fact far more commonalities and interactions with pleasure cycles linked to other pleasures such as food.

1.1. The human sexual pleasure cycle and its relation to other pleasure cycles

The term *sexual behavior* is rather broad and includes all behavioral parameters related to sexuality, similar to how *eating behavior* can be construed to include the behaviors related to eating. An interesting feature of these survival-related behaviors is their cyclical nature, whereby the behaviors wax and wane in frequency over time as different goals are identified, desired and consummated (Kringelbach et al., 2012).

Thus, the core of sexual behaviors can be defined as the repeating cycle of events and behaviors that can lead to reproduction, collectively termed the *sexual pleasure cycle* or sometimes the sexual response cycle (Fig. 1). In some species the biological features are such that they can only enter the sexual pleasure cycle at certain times of the year, while other species such as humans have the possibility to initiate sexual behavior year round.

In order to enter this cycle, we must first be motivated to mate, a process that may be triggered by various biological and psychological cues (i.e. sexual incentive stimuli). With sexual desire in place, and given the appropriate context, there may be physical consummation (stimulation of engorged genitalia) of the sexual need, leading to excitation and higher arousal (which may plateau for a while), culminating in ejaculation and/or orgasm. At least in male adult humans, this triggers a period of satiety or transient sexual quiescence after which sexual responsivity can be regained.

The very idea of a predictable sexual pleasure cycle, which is more similar than different for everyone, is of course rather abstract. It may not capture the huge variety of sexual responses and there may be significant differences between men and women, especially related to the orgasm phase. Nevertheless, this model can be rather helpful when aiming to identify the commonalities and differences in the brain networks supporting the different phases of the pleasure cycle, as outlined below. In particular, the cyclical model is useful for identifying the most important nodes and hubs of brain regions driving the functional changes in the brain networks sustaining or switching between the different phases of the pleasure cycle which can lead to changes in behavior.

It will also be clear from the above description that the dynamics of the sexual response cycle are very similar to those