

Men's genital structures mapped on the sensory cortex: fMRI evidence 464.04

Barry R. Komisaruk, Kachina Allen, Nan Wise, Eleni Frangos, and Wendy Birbano
 Department of Psychology, Rutgers University, Newark, NJ 07102

Introduction

Men's genitals are innervated by at least three pairs of nerves – pudendal, pelvic, and hypogastric (see Figure) [1]. The same three pairs of nerves in women provide sensory innervation of the clitoris, vagina/cervix, and uterus, respectively.

Using fMRI, we previously reported that self-stimulation of these genital regions in women activates different, but partially overlapping, regions of the paracentral lobule of the sensory cortex, as does nipple self-stimulation [2]. To our knowledge, a comparable comprehensive mapping of the genital structures in men has not been reported.

Previous work on genital mapping in men included a report of responses to rectal stimulation; however, it did not include activation in the somatosensory cortex [3]. Electrical stimulation of the dorsal nerve of the penis confirmed the earlier homuncular map of Penfield [4], i.e., that the evoked potentials were focused in the medial cortex (in the medial region of the paracentral lobule), i.e., in the genital region as represented in the homuncular map [5-8]. Other studies using mechanical or electrical stimulation of the penis identified a responsive region that was either medial [9] or more dorsolateral [10-12]; however, the latter may have been due to inadvertent stimulation of the groin. It is likely that, as in women [2], the different nerves providing sensory innervation of the genitals in men project to distinctly different regions of the sensory cortex.

To identify where the afferents from different genital components in men project onto the sensory cortex, we analyzed the localization of activation sites in sensory cortex in response to self-stimulation of the penile glans and shaft, scrotum, testicles, urethra, perineum, rectum, prostate and nipples.

Sensory Nerve	Female	Genital Region	Male
Pudendal	clitoris + labia + perineum	penis skin + scrotum + perineum	
Pelvic	vagina + cervix	penis deep + urethra + rectum?	
Hypogastric	ovary + uterus	testis + prostate	
Vagus (?)	vagina + cervix + uterus?	prostate?	

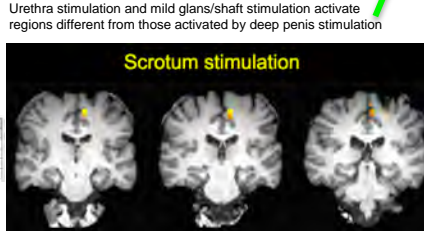
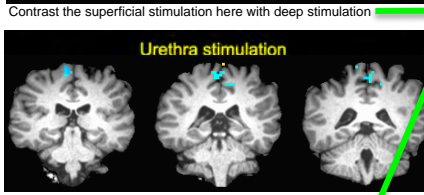
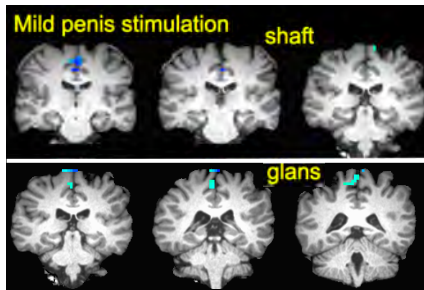
Methods

While lying in a 3T Siemens Trio scanner subjects were given visual cues to self stimulate each area of interest typically for 30sec-30sec rest x 5. Each subject used his right hand to stimulate his nipples, testicles and penis and a disposable curved lucite rod to stimulate his prostate, rectum and perineum. The urethra was stimulated using a thin (#8) commercial sterile catheter. Data processing was carried out in FSL and AFNI in Talairach space. The hand movements required for stimulation were modeled and subtracted from stimulation activations to ensure that stimulation activations were independent of the movements required to perform the stimulation. An ROI analysis was carried out on the paracentral lobules (AFNI TTAtlas) and thresholds were adjusted to see only the most active voxels.

Numbers of participants for the data figures:
 Shaft comparison deep versus mild, shaft, glans, scrotum, testicles, n=10
 Nipple, left/right, n=5
 Urethra, prostate, rectum, prostate-rectum; n=4.

References

- Netter FH. The Ciba collection of medical illustrations. Nervous system. Part I. Anatomy and physiology. Summit, NJ: Ciba Pharmaceutical; 1986.
- Komisaruk BR, Wise N, Fringes E, Liu W-C, Allen K, and Birbano W. Women's clitoris, vagina and cervix mapped on the sensory cortex: fMRI evidence. *J Sex Med* 2011; 8:2822-2834.
- Lots M, Wierlek B, Birbaumer N, Ehrhardt J, Grodd W, Erck P. Cerebral activation during anal and rectal stimulation. *Neuroimage* 2001;14:1027-34.
- Penfield W, Boldrey E. Somatic motor and sensory representation in the cerebral cortex of man as studied by electrical stimulation. *Brain* 1937;60:389-443.
- Makela JP, Ilman M, Jousmaki V, Numminen J, Lehecka M, Salenius S, Forss N, Hari R. Dorsal penile nerve stimulation elicits left-hemisphere dominant activation in the second somatosensory cortex. *Hum Brain Mapp* 2003;18:90-9.
- Nakagawa H, Namima T, Aizawa M, Uchi K, Kaiho Y, Yoshikawa E, Orihashi S, Nakasato N. Somatosensory evoked magnetic fields elicited by dorsal penile, posterior tibial, and median nerve stimulation. *Electroencephalogr Clin Neurophysiol* 1998; 108:57-61.
- Narici L, Modena I, Opsomer RJ, Pizzella V, Romani GL, Traversa R, Rossini PM. Neuroimaging somatosensory homunculus: A non-invasive approach in humans. *Neurosci Lett* 1991;2:51-4.
- Allison T, McCarthy G, Luby M, Puce A, Spencer D. Localization of functional regions of human mesial cortex by somatosensory evoked potential recording and by cortical stimulation. *Electroencephalogr Clin Neurophysiol* 1996;100:126-40.
- Hoelstege G, Georgiadis JR, Paans AM, Meiners LC, van der Graaf FH, Reinders AA. Brain activation during human male ejaculation. *J Neurosci* 2003;23:9185-93.
- Keil CA, Kriegstein K, Rostler A, Kleinschmidt A, Lauf H. The sensory cortical representation of the human penis: Revisiting somatotopy in the male homunculus. *J Neurosci* 2005;25:5984-7.
- Georgiadis J, Holstege G. Human brain activation during sexual stimulation of the penis. *J Comp Neurol* 2005;493:33-8.
- Bradley WE, Farrell DF, Ojemann G. Human cerebrocortical potentials evoked by stimulation of the dorsal nerve of the penis. *Somatosens Mot Res* 1998;15:118-27.



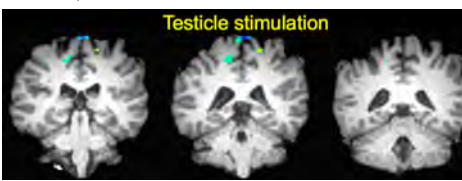
Scrotum stimulation (somatic) activates regions more shallow (i.e., closer to the midline) than testicle (visceral) stimulation



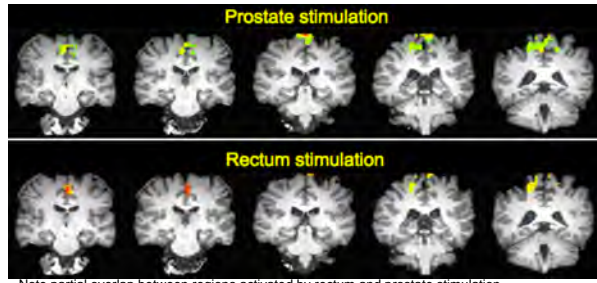
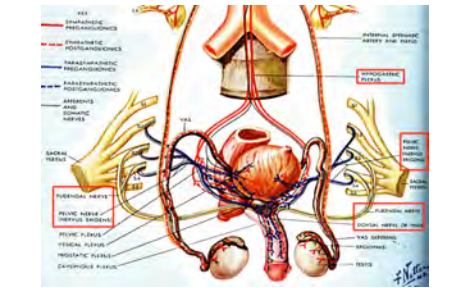
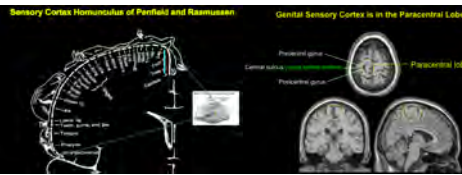
The head stabilizer for fMRI. The neck brace is fitted first (note extension up to occipital region), followed by the thermoplastic mesh molded to back of the head, then to the face.



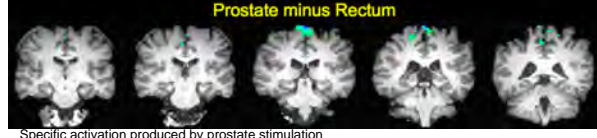
The differential activation is evidence that a second sensory nerve, probably the pelvic nerve, provides significant penile sensation (p<0.05 cluster thresholded)



The activation produced by testicle stimulation is different from that produced by scrotum stimulation, consistent with their innervation via different nerves.



Note partial overlap between regions activated by rectum and prostate stimulation



Specific activation produced by prostate stimulation



Nipple stimulation activated the genital sensory cortex, as we previously reported in women. Note the distinct contralateral activation pattern, indicative of a "hard-wired" pathway.

Conclusions

- The genital sensory cortex in men, mapped by fMRI, is located in the paracentral lobule, confirming and extending the Penfield homuncular map, which was based on electrical stimulation of brain.
- Penis mild, versus forceful, self-stimulation activated different, but adjacent, regions of the genital sensory cortex. This is most likely due to dual innervation -- differential activation of the pudendal nerve (surface skin) and the pelvic nerve (deep tissue) and their differential projections to the genital sensory cortex.
- Testicle self-stimulation (not mapped by Penfield) activated a different, but adjacent, region of the genital sensory cortex, different from scrotum stimulation.
- Prostate self-stimulation (also not mapped by Penfield) activated yet a different, also adjacent, region of the genital sensory cortex, which overlapped partially, but differed from, the regions activated by rectum stimulation.
- Nipple self-stimulation activated the genital sensory cortex, as we previously reported in women [2]. The contralateral activation provides evidence of a "hard-wired" pathway, rather than indirect via oxytocin-stimulated genital afference or via cognitive/experiential factors.
- Visceral stimulation responses tend to be located "deeper" (i.e., farther from the midline) than somatic stimulation responses.

Acknowledgments

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