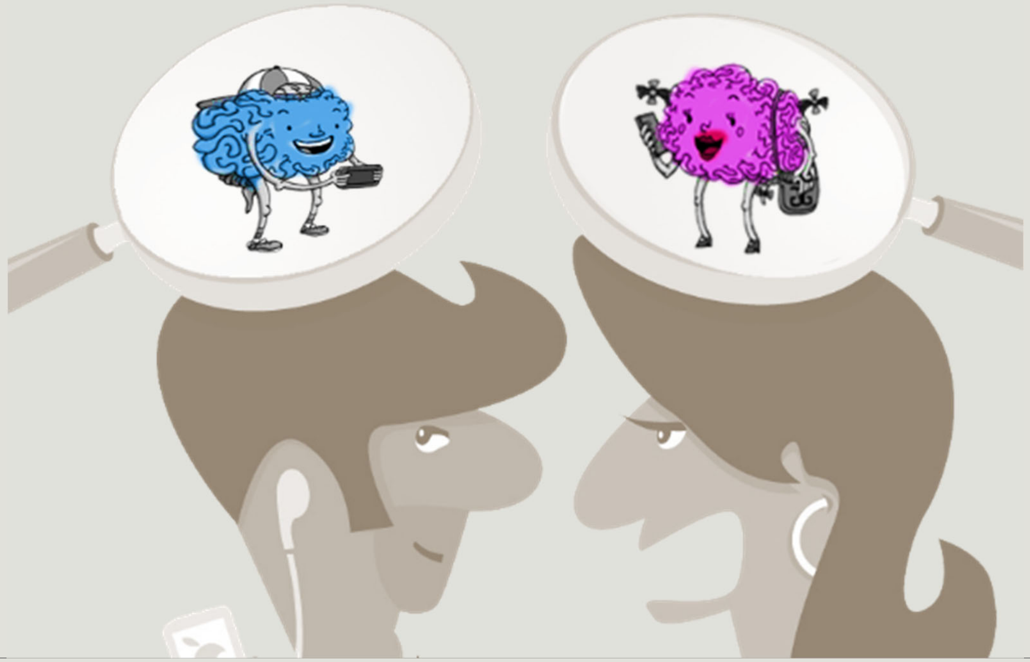
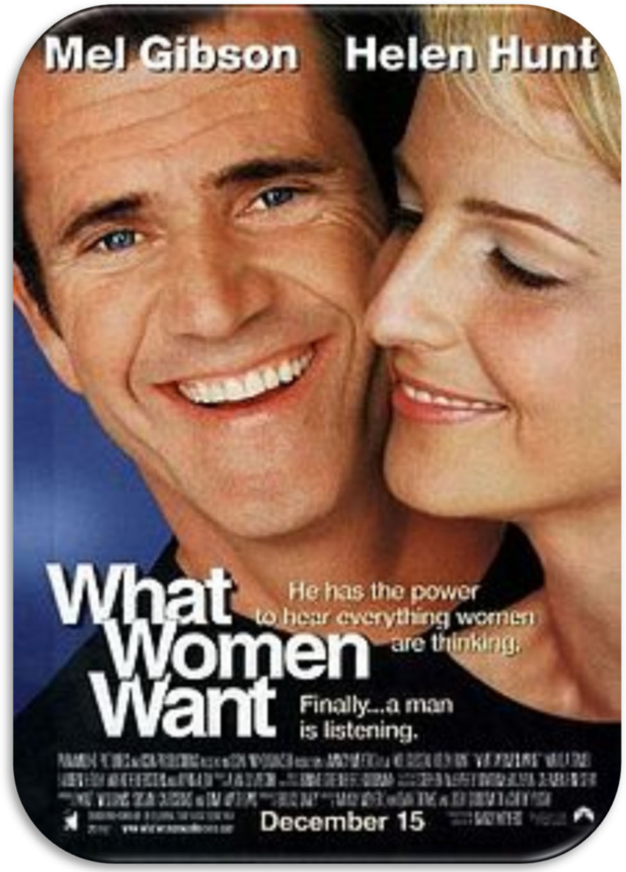


MARY E T BOYLE, PH.D. • DEPARTMENT OF COGNITIVE SCIENCE • UCSD

There is a grain of truth… why?

What would you hear if you gained the ability to hear women's thoughts?



anatomical

chemical

functional

male and female brains differ in

architecture & activity

language

memory

emotion

vision

hearing

navigation

Neural Circuitry Differences

Sexual dimorphisim in the brain translates into cognitive and behavioral differences between males and females.

sex-specific therapies for men and women

schizophrenia,
depression,
addiction &
post-traumatic stress disorder

Temporal Parietal Junction:

- The place where the temporal lobe (responsible for auditory functioning, memory and speech cognition) and the parietal lobe (responsible for sensory information) meet.
- It is more active in males.
- TPJ works to cognitively process emotion, which strengthens their ability to cognitively and analytically find a solution" to emotional problems as opposed to empathize – which women are more likely to do.

Parietal Cortex:

- The part of the brain responsible for spatial and somatosensory perceptions is larger in men.
- Some studies suggest that this may account for better spatial intelligence in men.

Amygdala:

- Fight or flight center – The amygdala serve as the alarm system for threats, fear and danger.
- It drives emotional impulses and can trigger protective aggression.
- It is larger in males than in females.
- It is more reactive in males than females which could account for the "short fuse" behavior more likely in males than in females.

Prefrontal Cortex:

- Executive function – planning
- Larger in women

Ventral Tegmental Area:

- The VTA is the "motivation center" of the brain, located deep below the basal ganglia. It produces dopamine, the "feel-good" transmitter for motivation and reward.
- Recall: VTA is activated strongly with drugs of abuse (heroin, cocaine, alcohol, gambling, video games ☺ etc.)
- The VTA is more active in males. This could account for why more males are alcoholics or drug addicts.

Dorsal Premammillary Nucleus:

- The PNd is part of the hypothalamus and contains projections that control territorial defensive behavior, fear and aggression.
- The PNd is larger in males and may be responsible for the protective, territorial behavior seen more frequently in males.

Figure adapted from: http://www.nypost.com/

Why do males and females differ?

Natural selection

Sexual selection

transportation

Survival of the Tattooed and Pierced?

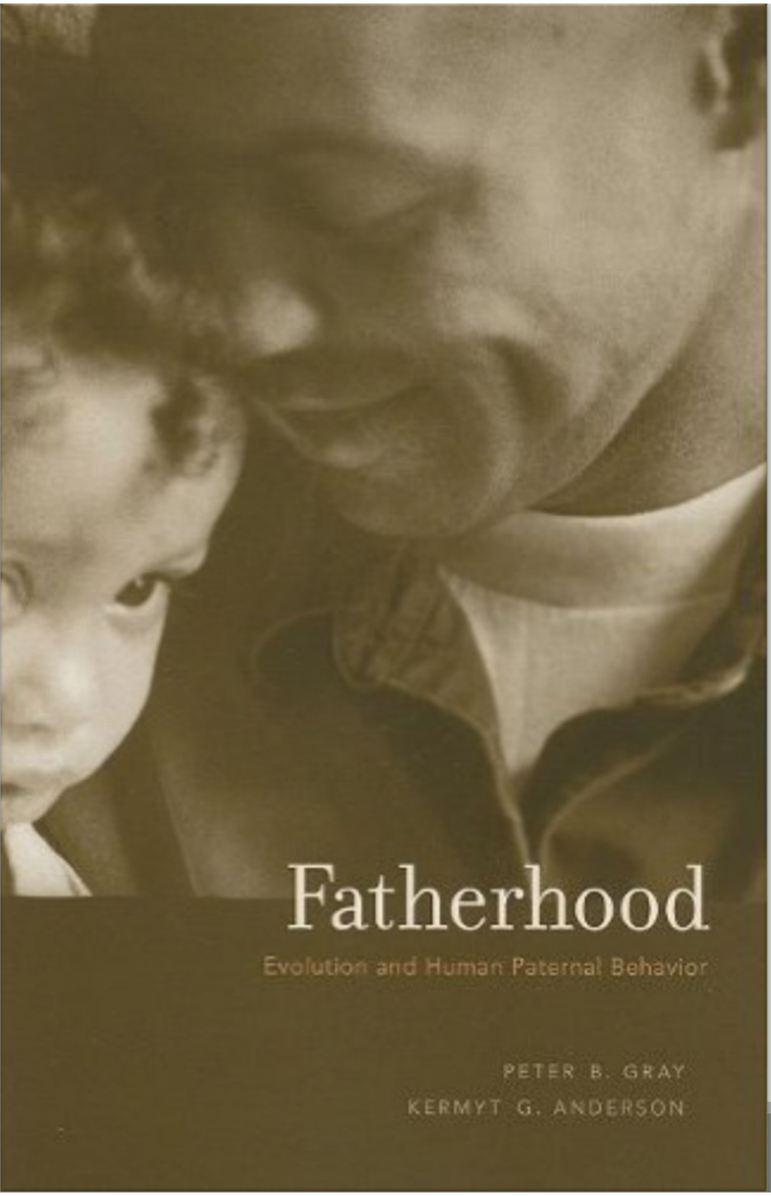
Body art may be evidence of high-quality genes in men

“ most people say they get tattoos or unconventional piercings to express individuality

getting stuck with needles can endanger one's health via infections

only those with high biological quality can afford such risky behavior ”

Scientific American mind – June 2010



What persuaded the male hominid to stick around after mating?

Sexual Conflict, Ecology, and Breeding Systems in Shorebirds

TAMÁS SZÉKELY, GAVIN H. THOMAS, AND INNES C. CUTHILL

Evolutionary biologists strive to understand the immense variation in animals' breeding systems. Shorebirds represent an ideal model system for this endeavor, because they exhibit diverse breeding systems that include monogamy, with the parents cooperating to rear the young; and polygamy by the male, the female, or both parents, with one parent taking full responsibility for incubating the eggs and rearing the young. Recent experimental manipulations, mathematical models, and phylogenetic analyses reveal that evolutionary pressures may diverge as they act on mated pairs of shorebirds, favoring one parent at a cost to the other. We argue that different reproductive payoffs for the male and the female have had fundamental implications for the evolution of diverse breeding systems.

Sexual conflict and sexual size dimorphism

Sexual conflict over care has profound implications for the sizes of males and females. Differing size of males and females within a species is termed sexual size dimorphism (SSD). Shorebirds exhibit an unusual range of SSD among birds: Male ruffs are about 1.7 times heavier than the females (i.e., male-biased SSD), whereas in the northern jacana (*Jacana spinosa*), the weight of the male is only about 0.6 times that of the female (i.e., female-biased SSD). The selective processes leading to these diverse SSDs are controversial because it is not clear whether selection toward large (or small) size in males, in females, or in both sexes may have produced different optimal sizes for adult males and females (Andersson 1994). One behavior that may contribute to SSD is mating competition, in which the members of one sex compete with each other to gain matings with the other sex. Those shorebird species in which males compete for females usually exhibit male-biased SSD, whereas those species in which females compete for males often have female-biased dimorphism (figure 5a).

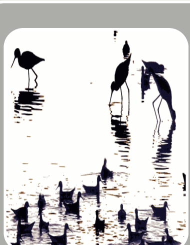
Exceptions to the rule…

Some shore birds

- Male stays at home
- cares for the young

Female is …

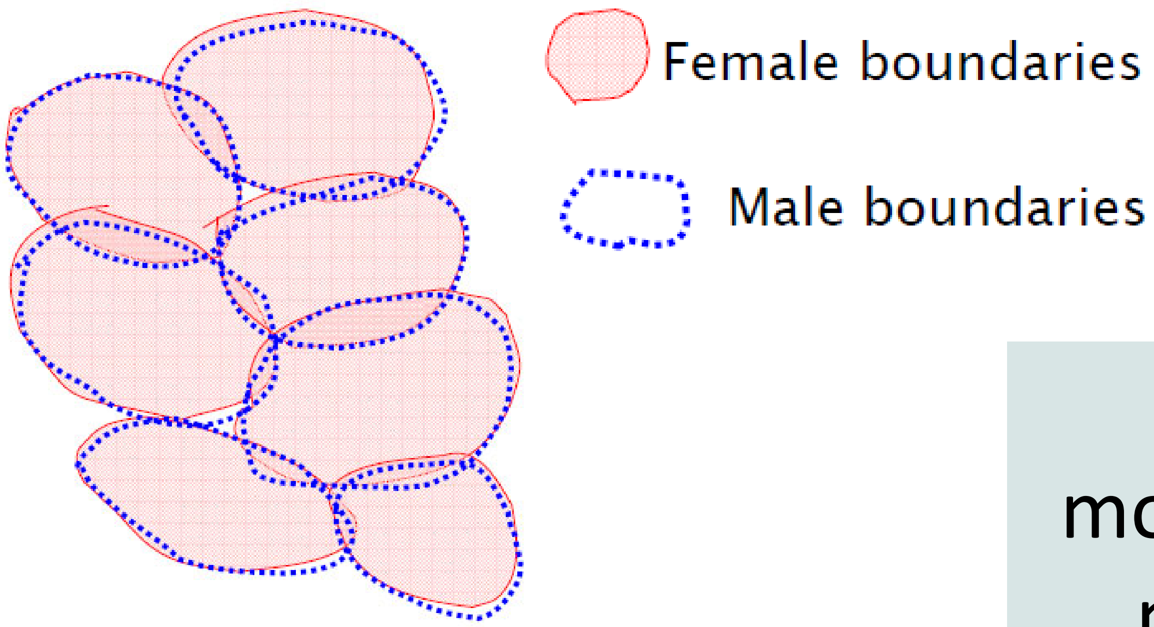
- Larger
- Brightly colored
- More aggressive



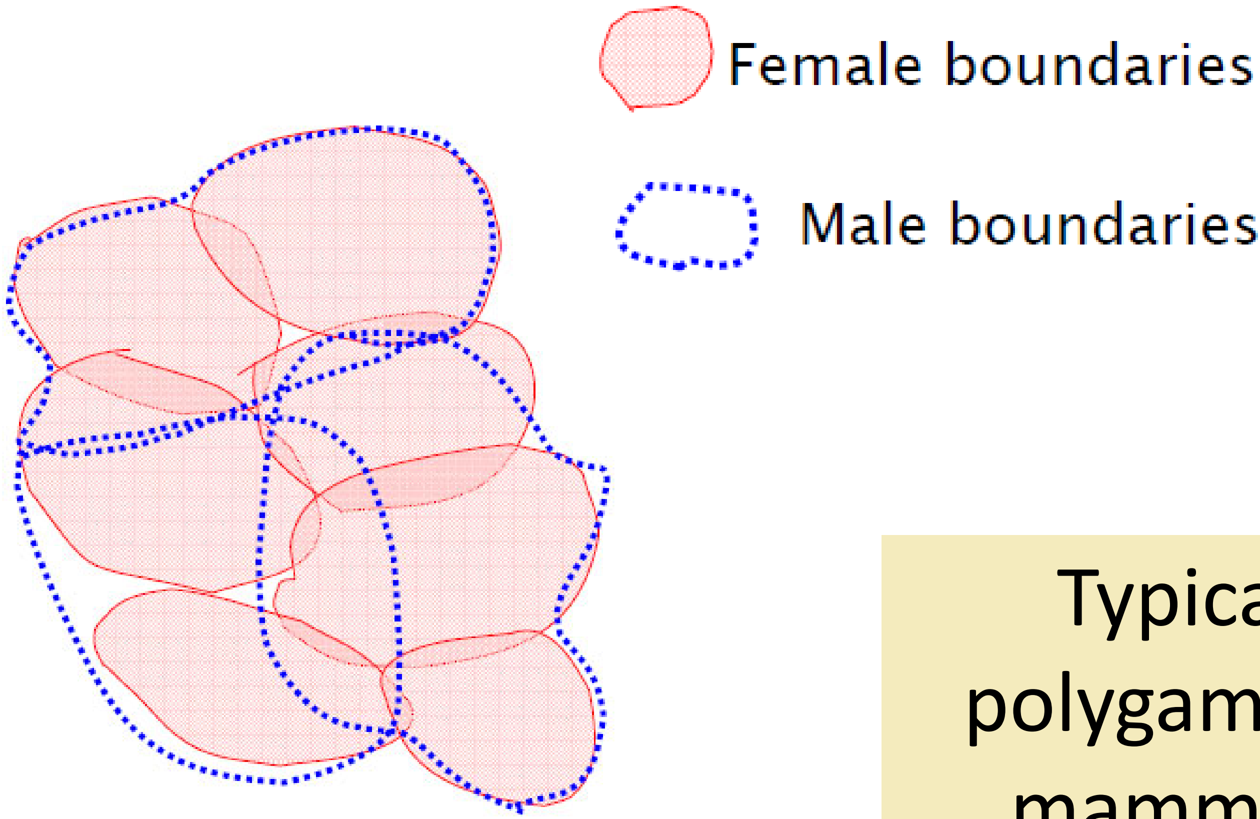
Child rearing

- Both parents participate
- Tend to be monogamous

Sexual abilities and spatial Abilities



Typical monogamous mammal.



Typical polygamous mammal.

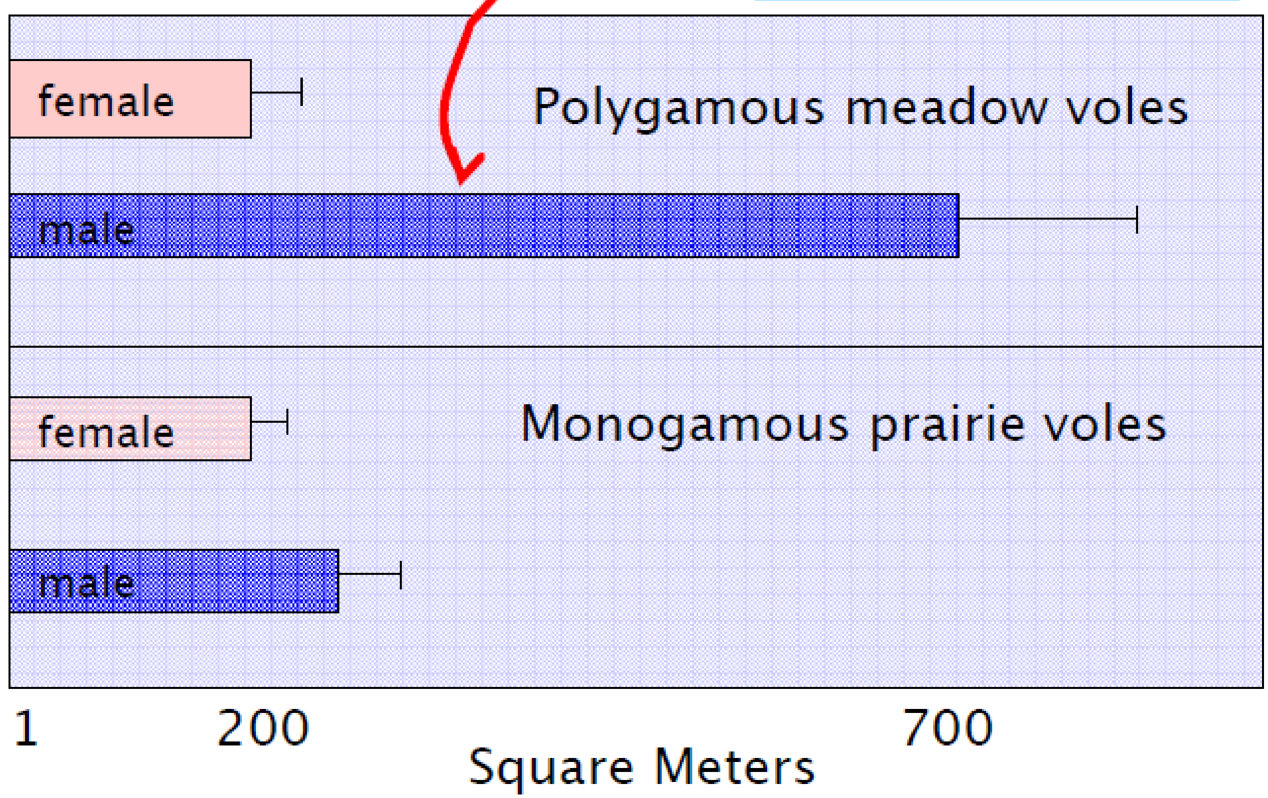
The tale of two voles…

Prairie vole
monogamous

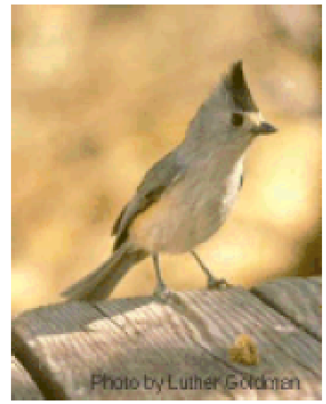
Meadow vole
polygamous

30 Day range size

Males with larger ranges had better spatial skills!!!



blue jays, nuthatches, and titmouses...



Tufted titmouse

All cache food over a large spatial area.

Their hippocampus **is** larger!!

Spatial memory and adaptive specialization of the hippocampus

David F. Sherry, Lucia F. Jacobs and Steven J. C. Gaulin

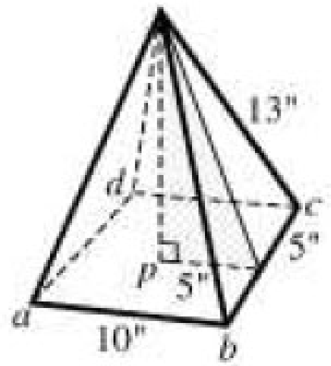
TINS, Vol. 15, No. 8, 1992

Kangaroo Rat

Male hippocampus
is larger

The hippocampus plays an important role in spatial memory and spatial cognition in birds and mammals. Natural selection, sexual selection and artificial selection have resulted in an increase in the size of the hippocampus in a remarkably diverse group of animals that rely on spatial abilities to solve ecologically important problems. Food-storing birds remember the locations of large numbers of scattered caches. P olygynous male voles traverse large home ranges in search of mates. Kangaroo rats both cache food and exhibit a sex difference in home range size. In all of these species, an increase in the size of the hippocampus is associated with superior spatial ability. Artificial selection for homing ability has produced a comparable increase in the size of the hippocampus in homing pigeons, compared with other strains of domestic pigeon. Despite differences among these animals in their histories of selection and the genetic backgrounds on which selection has acted, there is a common relationship between relative hippocampal size and spatial ability.

TINS, Vol. 15, No. 8, 1992



males and females might
differ in spatial memory ability

ELSEVIER

Brain and Cognition 54 (2004) 24–34

Brain and Cognition

www.elsevier.com/locate/b&c

Sex differences for selective forms of spatial memory

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Abstract

In the present study, a systematic comparison of sex differences for several tests of spatial memory was conducted. Clear evidence for more accurate male performance was obtained for precise metric positional information in a wayfinding task and in an object location memory task. In contrast, no sex difference characterized topological information processing (object-to-position assignment). Together, these findings provide further insight in the specificity of sex differences in spatial memory and in the functional architecture of spatial memory. Implications for the relevant evolutionary basis are discussed.

Women

- Higher verbal and nonverbal episodic memory tests.
- Outmatched males on visual recognition memory

Men

- Better on visuospatial episodic memory tests.
- Visual recognition difference disappeared when more male oriented objects were used.

The bottom line:

Women seem to have a better general (episodic) memory capacity.

This advantage can disappear or reverse if the information to be memorized includes a high degree of spatial processing.

The Eight Variables of Gender:

- Chromosomal gender
- Gonadal gender
- Prenatal hormone gender
- Internal accessory organs
- External genital appearance
- Pubertal hormone gender
- Assigned gender
- Gender identity

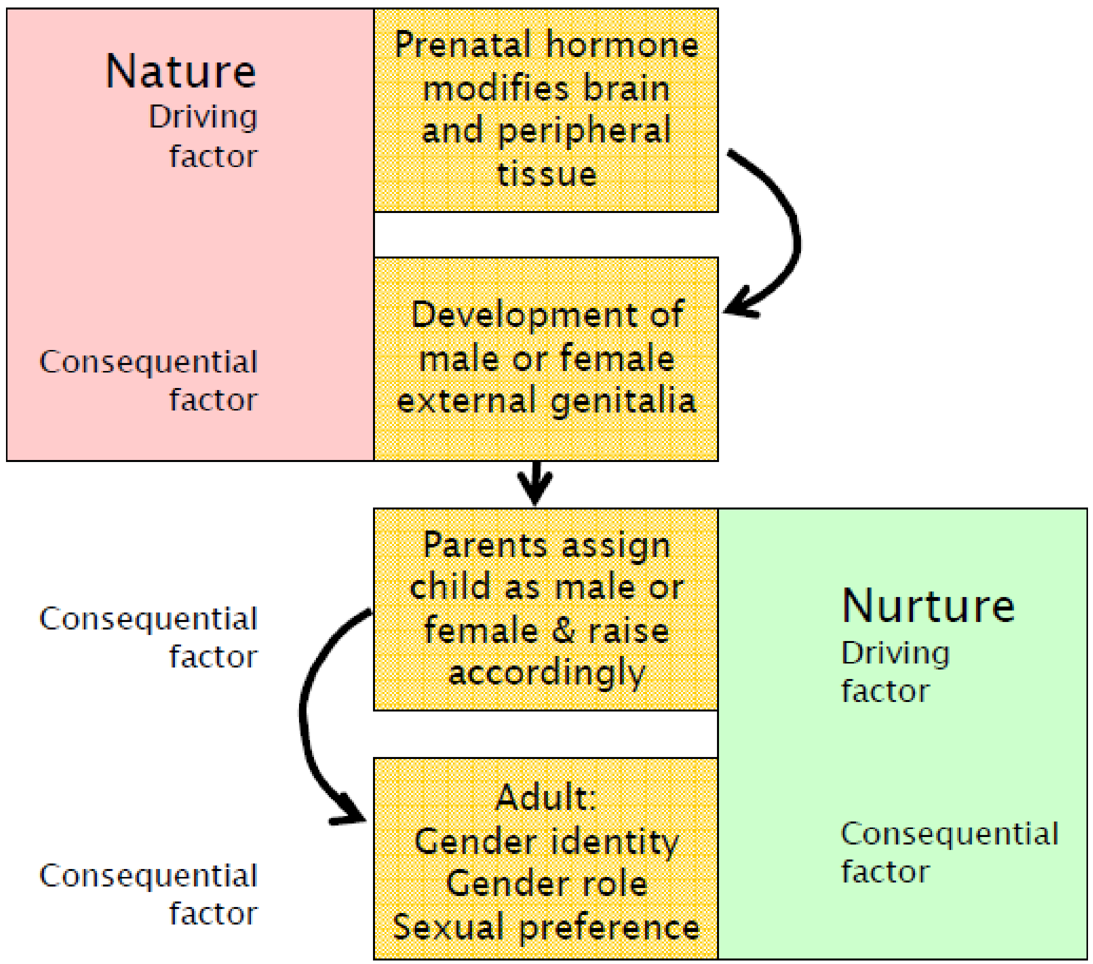
Gender Identity

- A private feeling that we are male or female.
- How does this develop?

Environmental influences?
We are born psychosexually neutral–
Nurture issue

VS

Nature



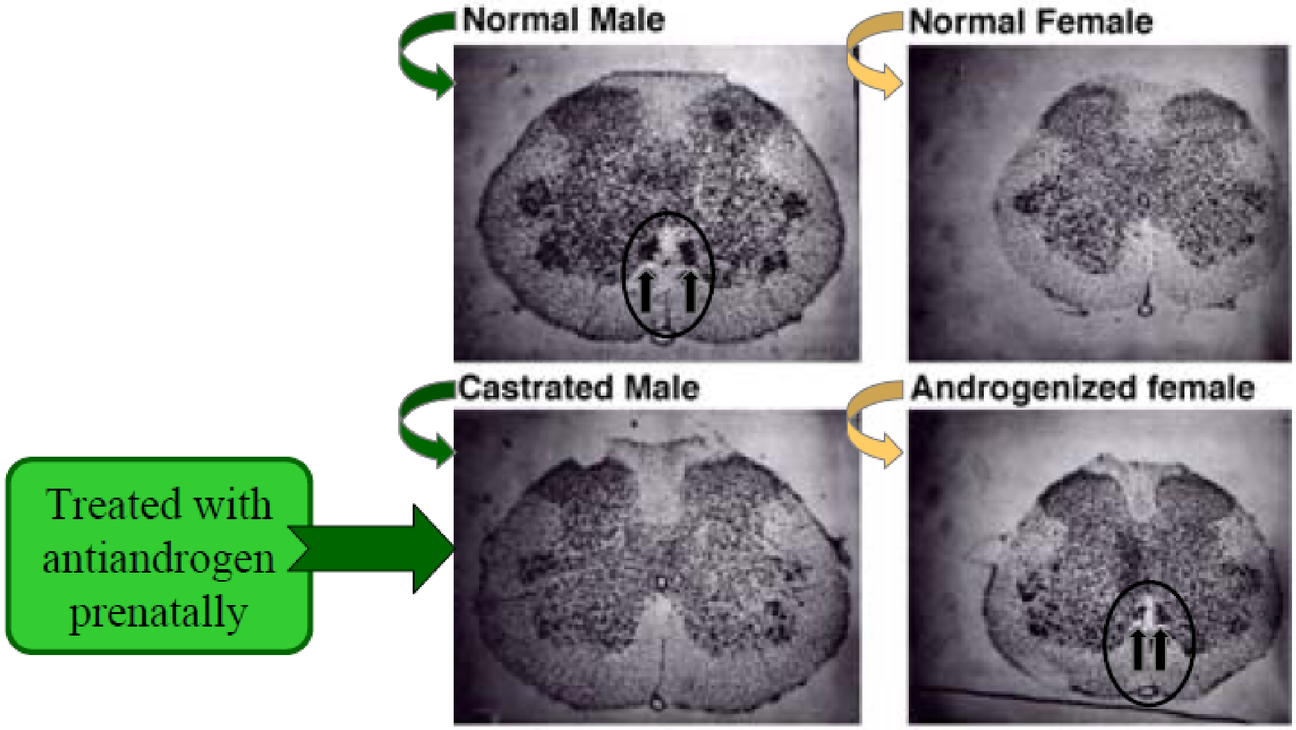
Nature
Driving
factor
Consequential
factor
Prenatal hormone modifies brain and peripheral tissue
Development of male or female external genitalia
Consequential
factor
Consequential
factor
Parents assign child as male or female & raise accordingly
Adult:
Gender identity
Gender role
Sexual preference
Nurture
Driving
factor
Consequential
factor

Neural Control of Sexual Behavior: Spinal Mechanisms

Males

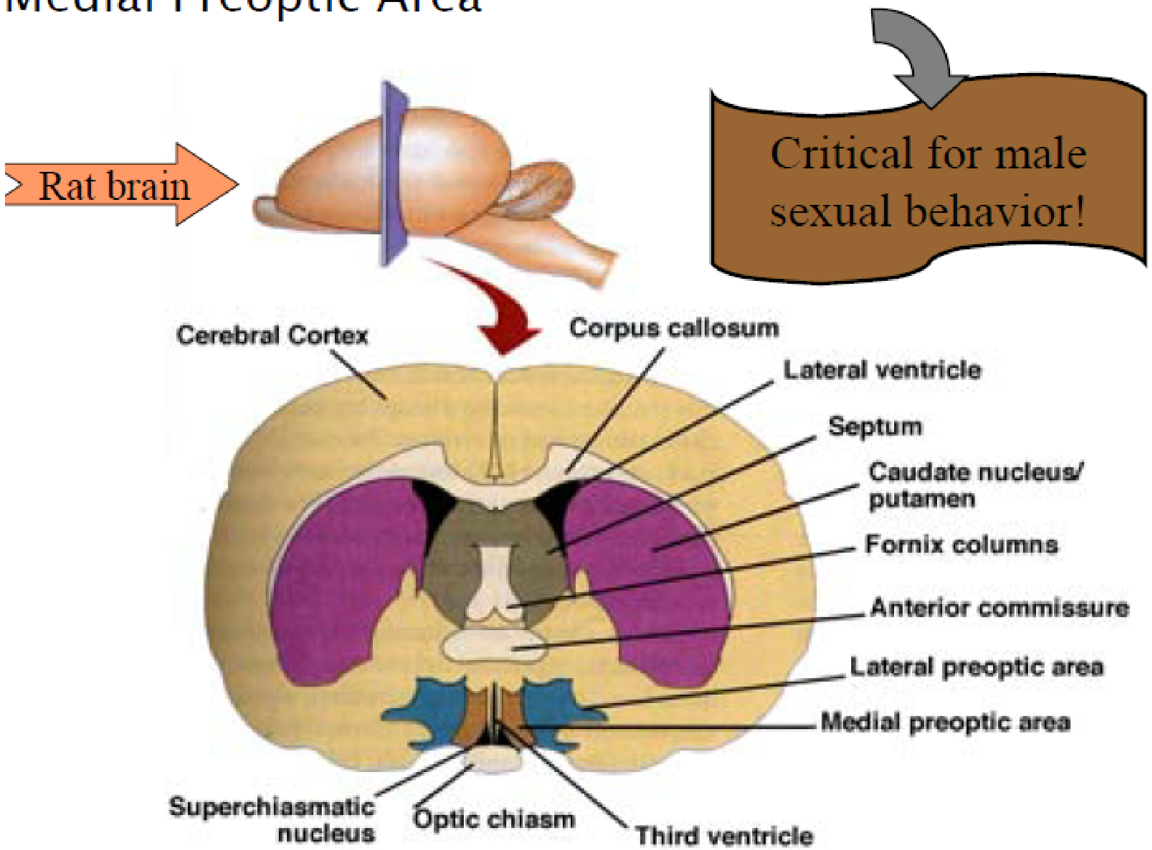
- Spinal Nucleus of the Bulbocavernosus (SNB)
- Lumbar region of spinal cord
- Ventral Horn
- Motor neurons that innervate the bulbocavernosus muscle
- Muscle at base of penis
- Involved in sexual activity

Neural Control of Sexual Behavior:
Spinal Mechanisms



Rat Spinal Cord @
Spinal Nucleus of the Bulbocavernosus

Medial Preoptic Area



Medial Preoptic Area

- Located rostral to the hypothalamus.
- Electrical stimulation elicits male copulatory behavior.
- Destruction of MPA permanently abolishes male sexual behavior.
- Region has high density of androgen receptors in male brains.

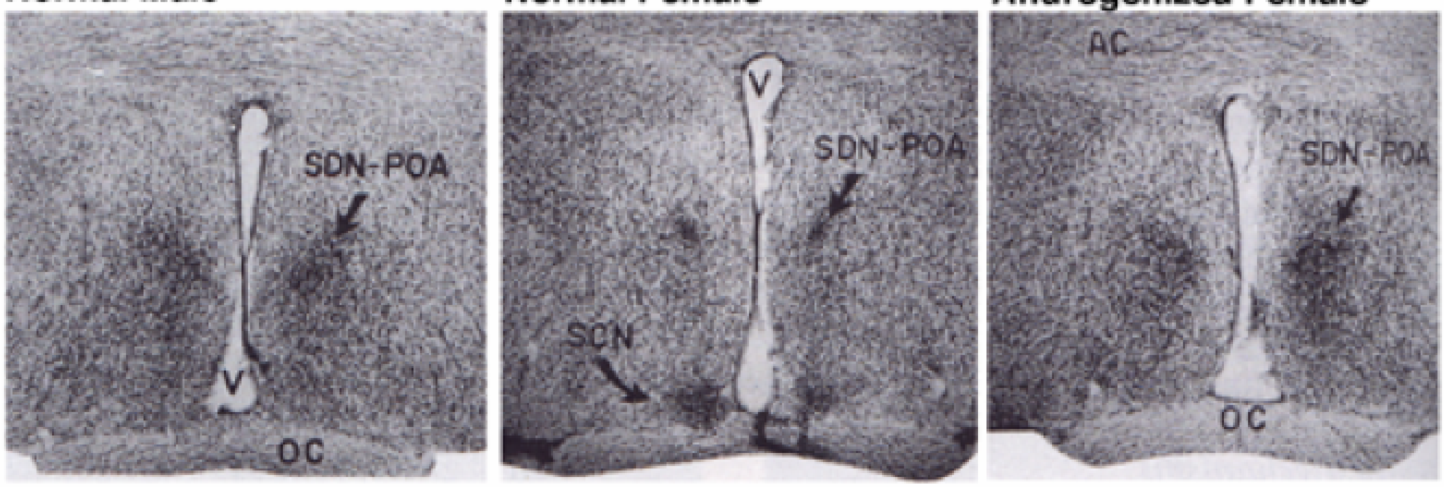
★ 5 times more than in female brains.

Sexually Dimorphic Nucleus...

- Region within MPA
- Size of nucleus is controlled by amount of androgens during fetal development.
- Androgenization critical period.
- Aromatized testosterone
- Size of SDN is sensitive to prenatal stress
- Size of SDN is related to sexual activity levels!
- Does not seem to be related motivation.

Rat Brain

Normal Male | **Normal Female** | **Androgenized Female**



SDN-POA
sexually dimorphic nucleus of the preoptic area

AC
anterior commissure
V third ventricle

OC
optic chiasm
SCN
suprachiasmatic nucleus

Neurotransmitters & Male Sexual Behavior

- Oxytocin - secreted by posterior pituitary
  - erection, ejacualtion and aftereffects
- Vasopressin - peptide hormone
- Dopamine - pursuit of females; copulation
- Serotonin - inhibitory effects on behavior

Enhanced partner preference in a promiscuous species by manipulating the expression of a single gene

Miranda M. Lim[1], **Zuoxin Wang**[2], **Daniel E. Olazábal**[1], **Xianghui Ren**[3], **Ernest F. Terwilliger**[3] & **Larry J. Young**[1]

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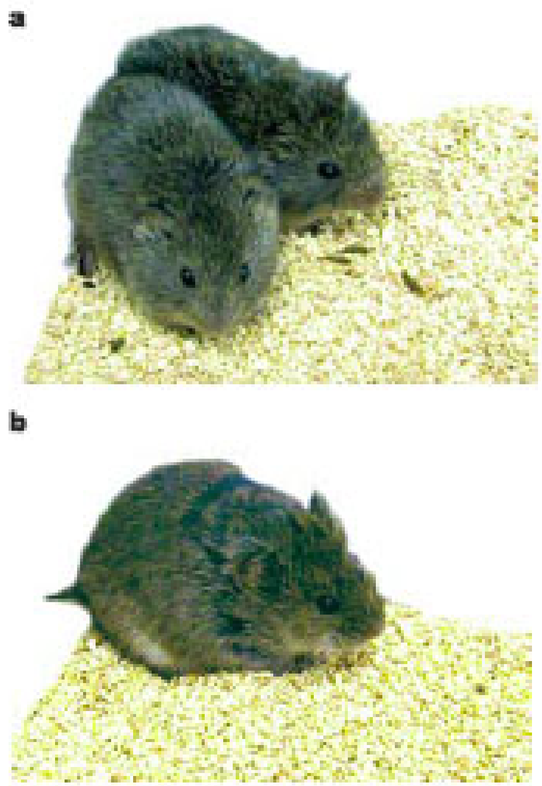
[3]*Harvard Institutes of Medicine and Beth Israel Deaconess Medical Center, Boston, Massachusetts 02115, USA*

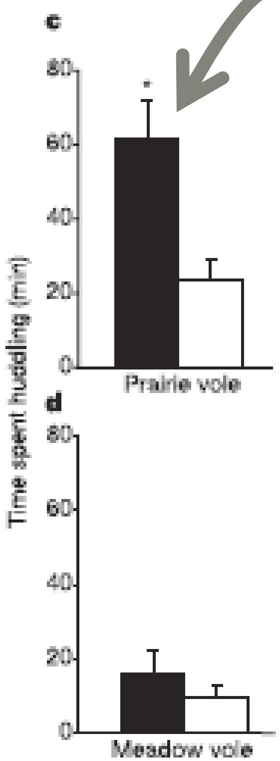
The molecular mechanisms underlying the evolution of complex behaviour are poorly understood. The mammalian genus *Microtus* provides an excellent model for investigating the evolution of social behaviour. Prairie voles (*Microtus ochrogaster*) exhibit a monogamous social structure in nature, whereas closely related meadow voles (*Microtus pennsylvanicus*) are solitary and polygamous[1]. In male prairie voles, both vasopressin and dopamine act in the ventral forebrain to regulate selective affiliation between adult mates, known as pair bond formation, as assessed by partner preference in the laboratory[2–4]. The vasopressin V1a receptor (V1aR) is expressed at higher levels in the ventral forebrain of monogamous than in promiscuous vole species[5], whereas dopamine receptor distribution is relatively conserved between species. Here we substantially increase partner preference formation in the socially promiscuous meadow vole by using viral vector *V1aR* gene transfer into the ventral forebrain. We show that a change in the expression of a single gene in the larger context of pre-existing genetic and neural circuits can profoundly alter social behaviour, providing a potential molecular mechanism for the rapid evolution of complex social behaviour.

Comparison of brain neurochemistry and behavior in prairie and meadow voles.



Although prairie voles and meadow voles are similar in physical appearance, prairie voles are highly affiliative as depicted here in 'huddling' side by side (a), whereas meadow voles are solitary (b).

Partner preference test.

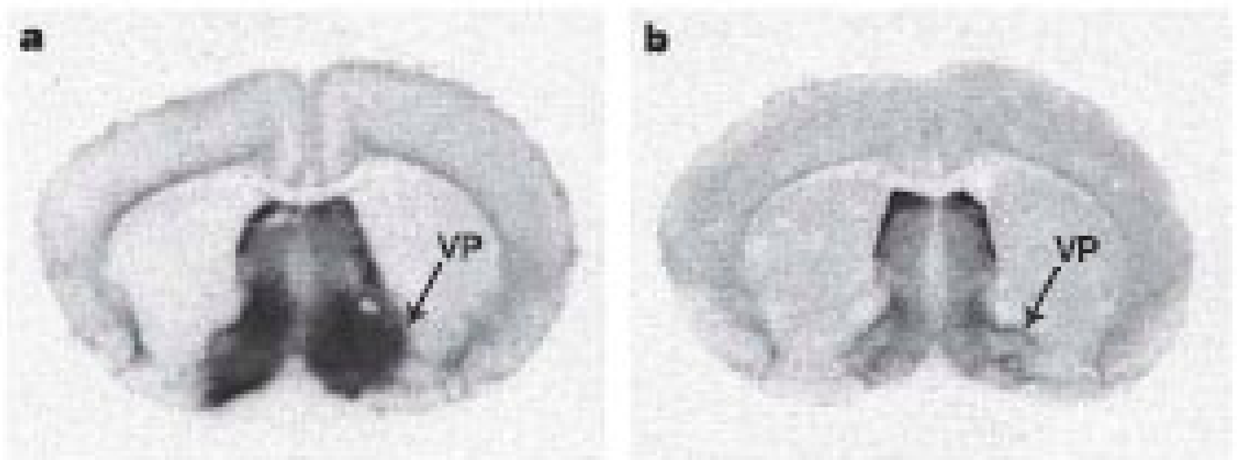


After mating and cohabitating with a female, a **male prairie vole tended to spend significantly more time** in contact with the partner (filled columns) than the stranger (open columns) (c), whereas meadow voles do not form partner preferences and spent relatively little time huddling with either female (d).

V1aR autoradiography at the level of the ventral pallidum.

Meadow vole overexpressing the V1aR gene

control vector expressing the lacZ gene



More huddle time!

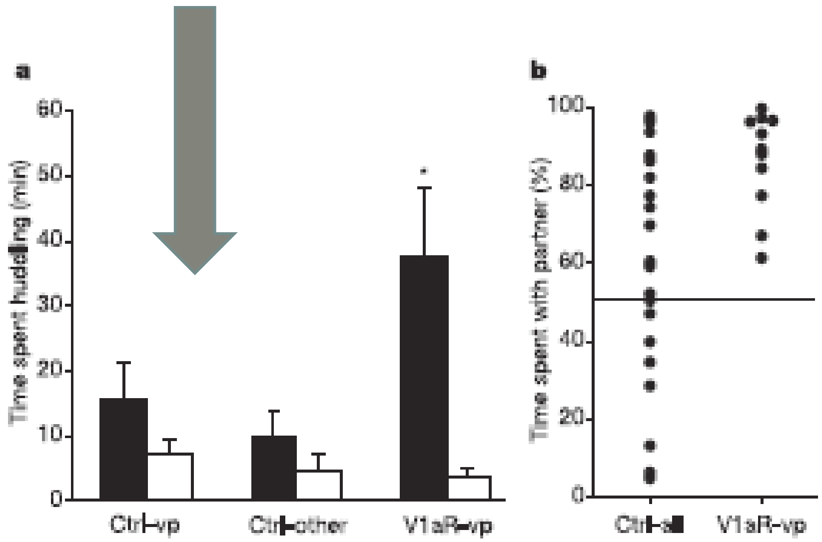


Figure 3 Partner preference test. **a**, V1aR-vp meadow voles spent significantly more time huddling with the partner (filled column) than the stranger (open column), whereas control animals (Ctrl-vp) and stereotactic misses (Ctrl-other) did not ($P < 0.01$, Student's t-test). Error bars, standard error. **b**, A plot of the percentage of time spent with the partner for each subject indicates a shift from randomly distributed preferences in the control groups to 100% of animals preferring the partner in the V1aR-vp group ($P < 0.001$, χ^2 analysis). The y axis was calculated as the time spent huddling with the partner divided by the total time spent huddling with the partner and stranger, multiplied by 100.

Proc. Natl. Acad. Sci. USA
Vol. 89, pp. 5981–5985, July 1992
Neurobiology

Oxytocin receptor distribution reflects social organization in monogamous and polygamous voles

(microtine/affiliation/parental behavior/amygdala/septum)

THOMAS R. INSEL AND LAWRENCE E. SHAPIRO

Laboratory of Neurophysiology, National Institute of Mental Health, P.O. Box 289, Poolesville, MD 20837

Communicated by Peter Marler, March 20, 1992

In the **prairie vole**, oxytocin receptor density was highest in the prelimbic cortex, bed nucleus of the stria terminalis, nucleus accumbens, midline nuclei of the thalamus, and the lateral aspects of the amygdala.

These brain areas showed little binding in the **polygamous montane vole**, in which oxytocin receptors were localized to the lateral septum, ventromedial nucleus of the hypothalamus, and cortical nucleus of the amygdala.

ABSTRACT The neuropeptide oxytocin has been implicated in the mediation of several forms of affiliative behavior including parental care, grooming, and sex behavior. Here we demonstrate that species from the genus *Microtus* (voles) selected for differences in social affiliation show contrasting patterns of oxytocin receptor expression in brain. By *in vitro* receptor autoradiography with an iodinated oxytocin analogue, specific binding to brain oxytocin receptors was observed in both the monogamous prairie vole (*Microtus ochrogaster*) and the polygamous montane vole (*Microtus montanus*). In the prairie vole, oxytocin receptor density was highest in the prelimbic cortex, bed nucleus of the stria terminalis, nucleus accumbens, midline nuclei of the thalamus, and the lateral aspects of the amygdala. These brain areas showed little binding in the montane vole, in which oxytocin receptors were localized to the lateral septum, ventromedial nucleus of the hypothalamus, and cortical nucleus of the amygdala. Similar differences in brain oxytocin receptor distribution were observed in two additional species, the monogamous pine vole (*Microtus pinetorum*) and the polygamous meadow vole (*Microtus pennsylvanicus*). Receptor distributions for two other neurotransmitter systems implicated in the mediation of social behavior, benzodiazepines, and μ opioids did not show comparable species differences. Furthermore, in the montane vole, which shows little affiliative behavior except during the postpartum period, brain oxytocin receptor distribution changed within 24 hr of parturition, concurrent with the onset of maternal behavior. We suggest that variable expression of the oxytocin receptor in brain may be an important mechanism in evolution of species-typical differences in social bonding and affiliative behavior.

show comparable species differences. Furthermore, in the montane vole, which shows little affiliative behavior except during the postpartum period, brain oxytocin receptor distribution changed within 24 hr of parturition, concurrent with the onset of maternal behavior. We suggest that variable expression of the

Changes in oxytocin receptor distribution coincided with changes in behavior!

"I'm going to Venus. He's going to Mars."