

Play Is All You Need

WR CJ MMZ

Attention Is All You Need

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Illia Polosukhin*[‡] illia.polosukhin@gmail.com			

*Equal contribution. Listing order is random. Jakob proposed replacing RNNs with self-attention and started the effort to evaluate this idea. Ashish, with Illia, designed and implemented the first Transformer models and has been crucially involved in every aspect of this work. Noam proposed scaled dot-product attention, multi-head attention and the parameter-free position representation and became the other person involved in nearly every detail. Niki designed, implemented, tuned and evaluated countless model variants in our original codebase and tensor2tensor. Llion also experimented with novel model variants, was responsible for our initial codebase, and efficient inference and visualizations. Lukasz and Aidan spent countless long days designing various parts of and implementing tensor2tensor, replacing our earlier codebase, greatly improving results and massively accelerating our research.

[†]Work performed while at Google Brain.

[‡]Work performed while at Google Research.



- 25 **Petra:** Und dann? Hast du am Freitag Zeit? Trinken wir zusammen Kaffee!
- Wang Hongliang:** Nein, das geht auch nicht. Am Freitag gibt es⁵ immer Hausaufgaben.
- Petra:** Lernen, lernen, immer lernen. Du hast nie Zeit für das Leben und für die Freunde. Du liest und liest.
- 30 **Wang Hongliang:** Schläfst du eigentlich noch? Isst du eigentlich noch?
- Wang Hongliang:** Oh, wie spät ist es jetzt? Was? Schon fünf vor elf? Der Unterricht beginnt.

Why do easterners and westerners have
different attitudes toward learning and life?

Text 2 Wann studierst du eigentlich?

Wang Hongliang: Sag mal, hast du heute Nachmittag Zeit? Ich mache am Donnerstag eine Prüfung und habe noch Fragen.↵

Peter: Das geht leider nicht. Ich spiele Fußball. Vielleicht morgen Nachmittag?↵

Wang Hongliang: Morgen? Dienstag? OK, aber erst nach halb fünf. Ich habe bis Viertel nach vier Vorlesung.↵

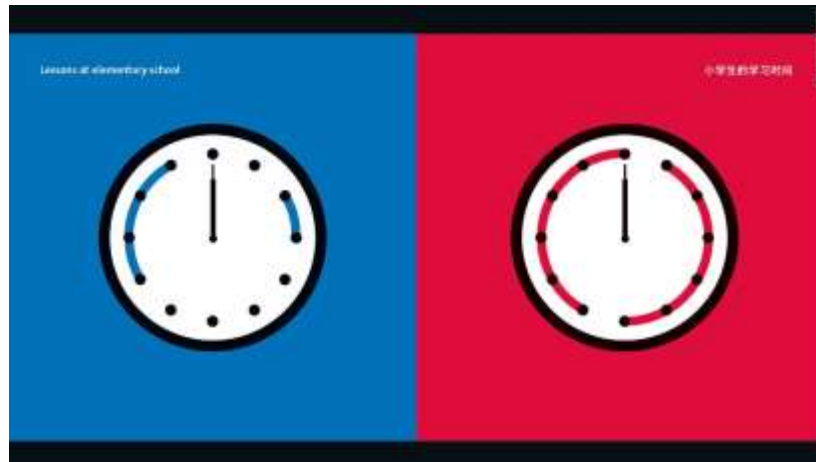
Peter: Erst nach halb fünf? Das geht leider wieder nicht. Julia gibt am Abend eine Party.↵

Wang Hongliang: Dann am Mittwoch? Hast du da Zeit?↵

Peter: Am Mittwoch Vormittag treibe ich sport. Und am Nachmittag, hm ... ja, da kommt Thomas. Und wir trinken zusammen Kaffee.↵

Wang Hongliang: Ja ja, Kaffee trinken, Musik hören, Sport treiben, Fußball spielen. Sag mal, Peter, wann studierst du eigentlich?↵

Stereotypes about eastern and western education



© tineyes



What are animals' natural instincts?

The diverse ways of playing in the animal kingdom



PART I: What is play behavior?

—WR

PART II: How do animals benefit from play behavior?

—CJ

PART III: Why do adults play less than juveniles?

—MMZ

PART I: What is play behavior?

(Definition and forms)

—WR

Can animals play?



An overview of playful behavior among animals

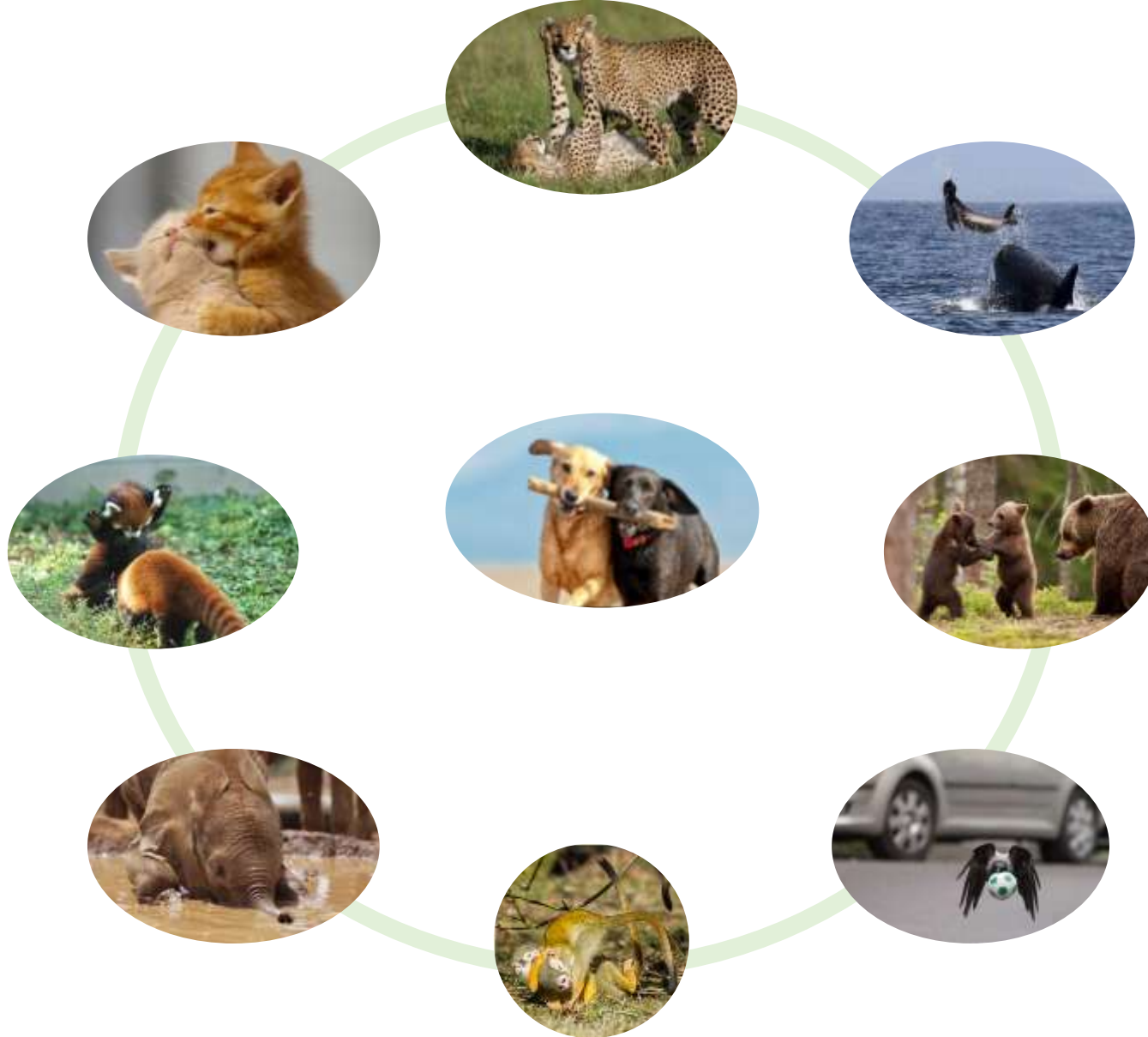
What is playful behavior?

Why do animals play? Is play an instinctive behavior?

Why are rats the best model for studying playful behavior?

- What is playful behavior?
- Why do animals play? Is play an instinctive behavior?
- Why are rats the best model for studying playful behavior?

Playful behavior plays a crucial role in the lives of animals



What is play behavior?

Play is a normative child behavior with defining characteristics. Specific subtypes of play are present from infancy throughout childhood, and include **sensorimotor or exploratory play**, **functional play**, **constructive play**, **pretend play**, and **rough-and-tumble play**. Play can also be categorized on the basis of the social aspects of the interaction, from solitary play to cooperative play with peers.

- (1) did not contribute to immediate survival strategies
- (2) was intrinsically rewarding (not lead to obvious, immediate and adaptive results)
- (3) differed from functional behaviour in form
- (4) was repeated but not stereotyped (exaggeration of movements, repetition of motor acts, and fragmentation or disordering of sequences of motor acts)
- (5) was initiated under stress-free conditions



(Paul martin and T. M. Caro . *Behaviour*. 1985.)

(H. S. Galpayage Dona et al . *Animal Behaviour*. 2022.)

Different classification of playful behavior

- ❑ **Locomotor play** refers to apparently spontaneous movements which carry the individual about its environment; include running, leaping, pirouetting, head shaking, heel kicking, and whirling around.
- ❑ **Object play** refers to play directed at inanimate objects; can be performed alone or with conspecifics.
- ❑ **Social play** (rough-and-tumble play) refers to play directed at conspecifics; involves vigorous interactions between two or more animals.



(Graham and Burghardt. 2010; Pellis and Pellis. 2009; Vanderschuren et al. 1997)

Playful behavior exists in various animals and varies greatly

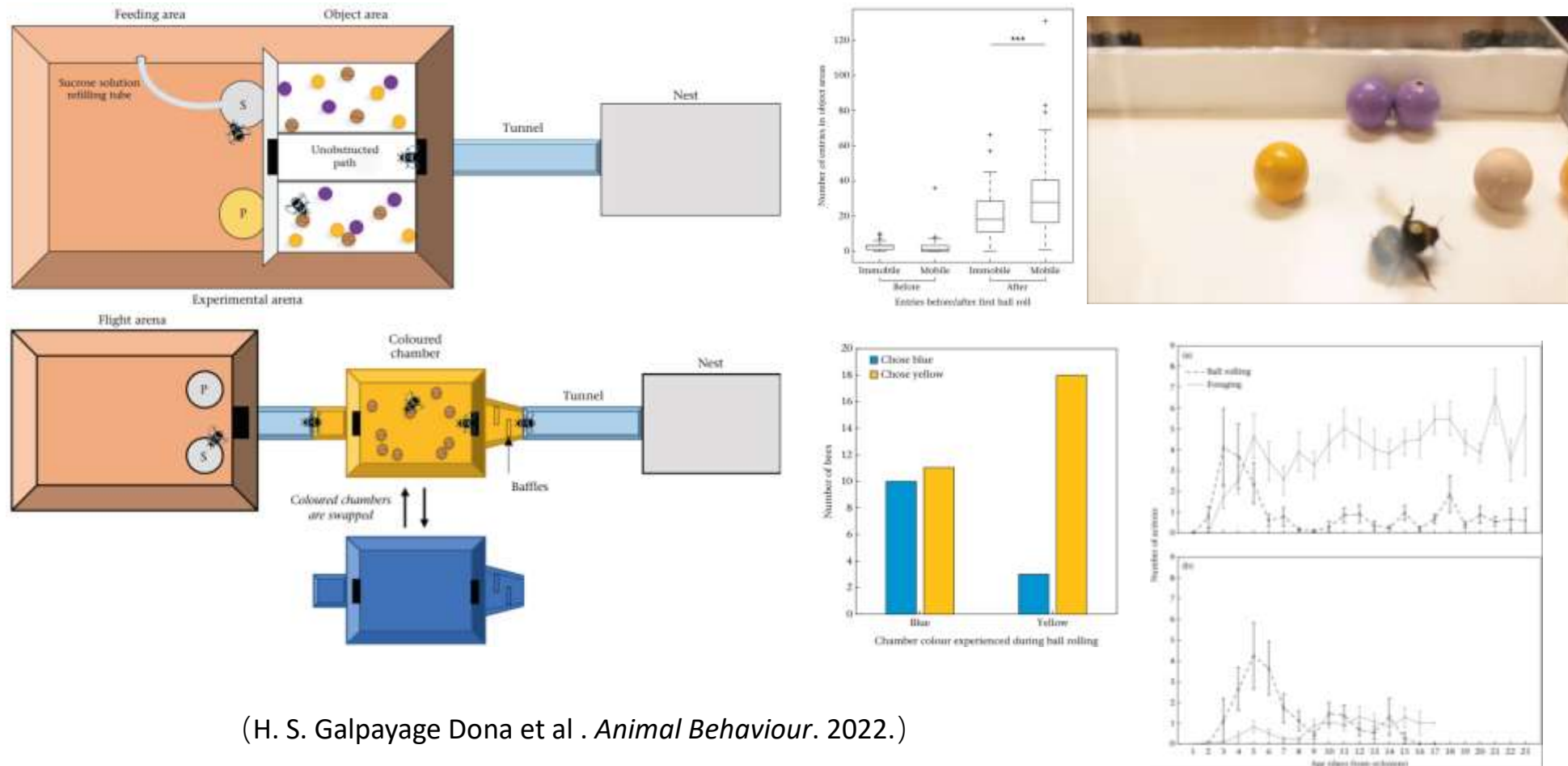
What animals engage in play?



- Play is well-developed in primates, rodents, carnivorans, ungulates, elephants, and cetaceans.
- These playful orders contain numerous species that show great diversity in habitat, home range size, locomotor pattern, life history, body size, social organization, and diet.

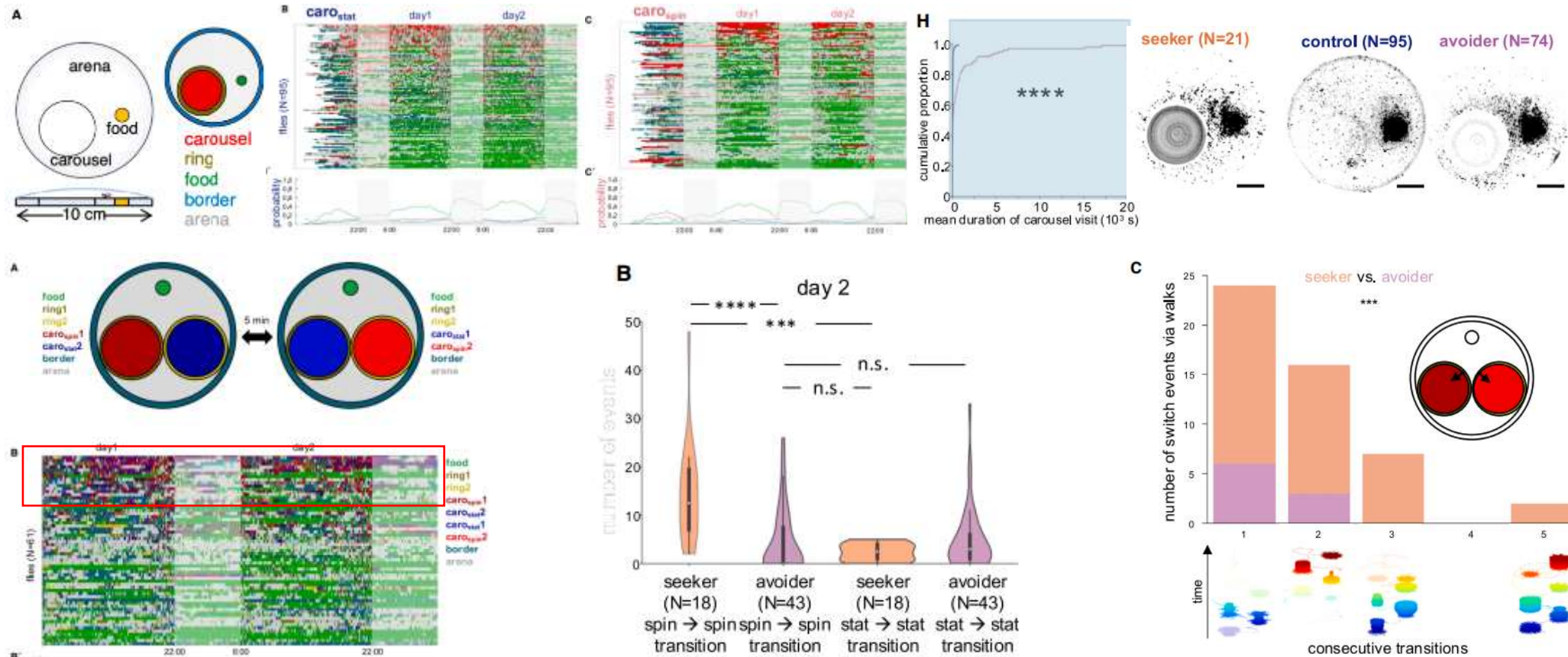
(H. S. Galpayage Dona et al . *Animal Behaviour*. 2022.)

Bumble Bees also have the behavior of playing games for fun, and male rolled individual balls for longer durations than females



(H. S. Galpayage Dona et al . *Animal Behaviour*. 2022.)

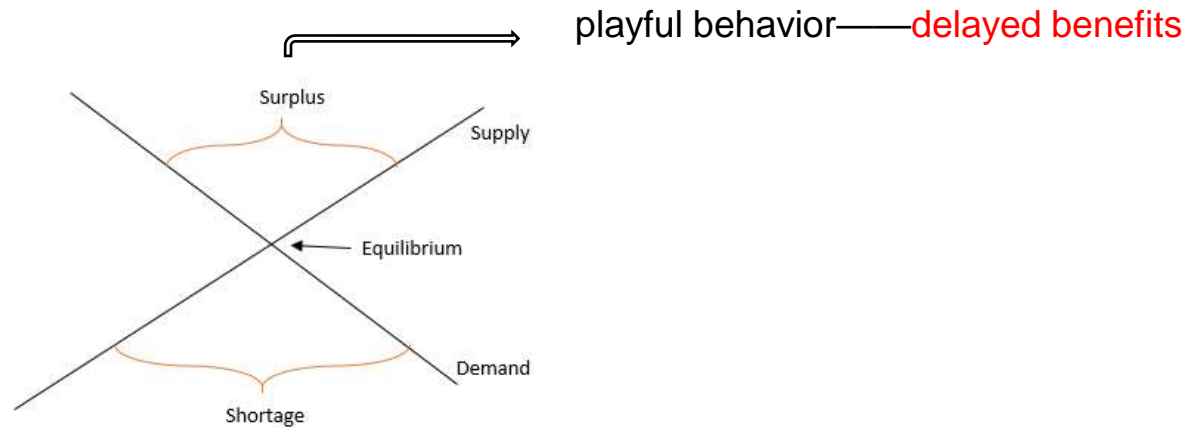
Play-like behavior exhibited by the vinegar fly *Drosophila melanogaster*



(Tilman Triphan et al . *Current Biology*. 2025.)

- What is playful behavior?
- Why do animals play? Is play an instinctive behavior?
- Why are rats the best model for studying playful behavior?

Why do animals play and what are the benefits of playing?

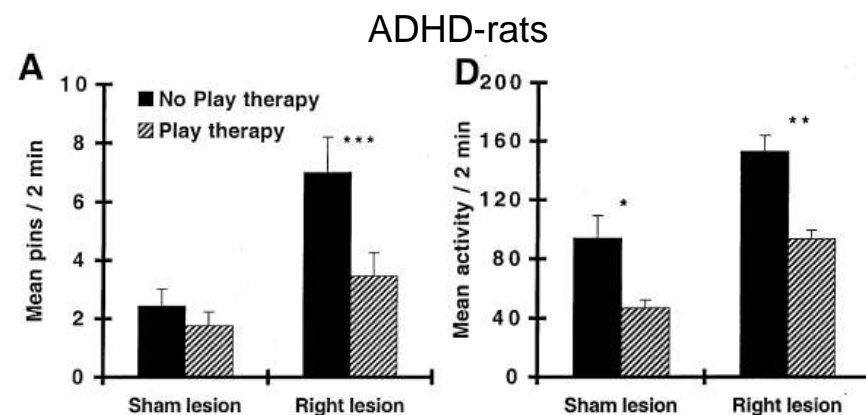
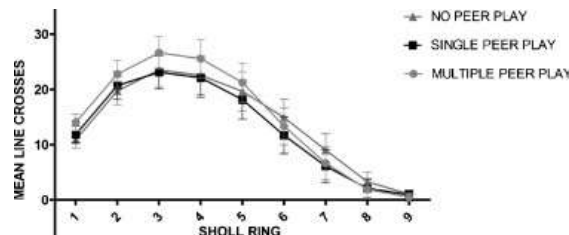
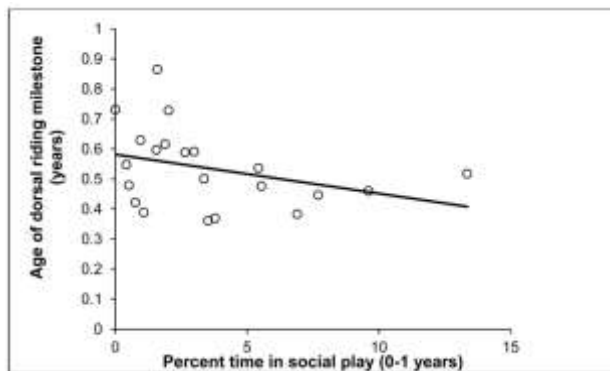


Surplus Resource Theory

- The origins of play are found in animals with **sufficient metabolic resources** for sustained activity and complex behavior that needs to be deployed in varying ways. They also need the time and safety to engage in behavior that may **not** be **immediately advantageous**, but through which animals learn or perfect **behavioral skills, social acumen, physiological or perceptual abilities**, and other means that **enhance survival compared to non-playing conspecifics**.
- In its ancient and more primitive incarnations, playing may not have had any specific advantage over non-playing, but eventually **the benefits outweighed** the often **serious costs** of play in energy and risks of injury and predation.

(Gordon M. Burghardt. *Current Biology*. 2015.)

The significance and benefits of playing



- Physiological aspect:
Develop motor skills 、 Train for the unexpected
- Cognitive aspect:
Assess one's own physical and cognitive capabilities
- Social aspect:
Assess the reliability and capabilities of potential social partners、 Learn social norms、 Foster social cohesion

(Matthew R. Heintz et.al . *Am J Primatol.* 2017.)

(Heather C. Bell et.al . *Behavioural Brain Research.* 2010.)

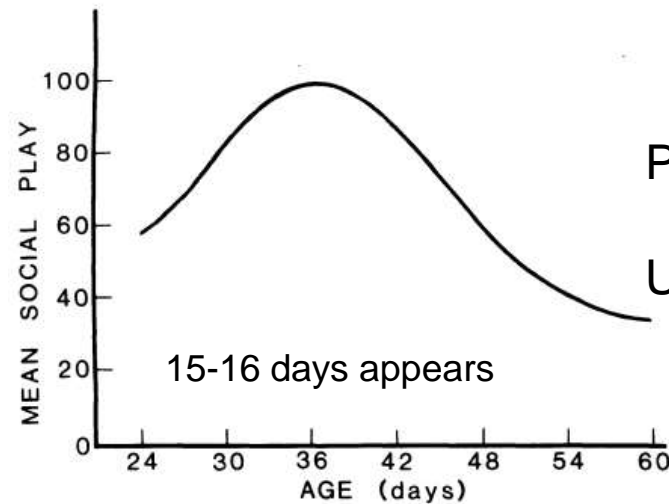
(Jaak Panksepp et.al . *Brain and Cognition* .2003.)

Playing is an instinctive behavior

Psychological aspect:



Evolutionary perspective:



Prejuvenile(decreases with sexual maturity)

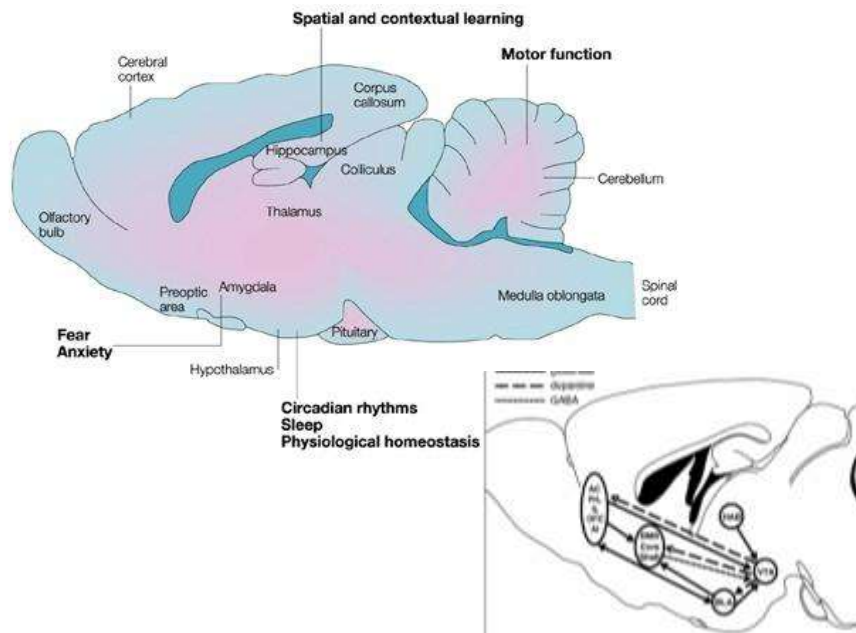
Universality(exists in multiple species)

(D. H. THOR and W. R. HOLLOWAY, JR. *Bulletin of the Psychonomic Society*. 1984.)

(Elena I Varlinskaya et.al. *Physiology & Behavior*. 1999.)

- What is playful behavior?
- Why do animals play? Is play an instinctive behavior?
- Why are rats the best model for studying playful behavior?

The rat as an optimal animal model to study the neurobiology of play



- Play in the rat is easily quantified, tightly regulated, and can be modulated by genetic factors and postnatal experiences (rough-and-tumble play) ;
- Brain areas most likely to be involved in the modulation of play include regions within the prefrontal cortex, dorsal and ventral striatum, some regions of the amygdala, and habenula.
- It has a good foundation of neural modulators and neural circuits

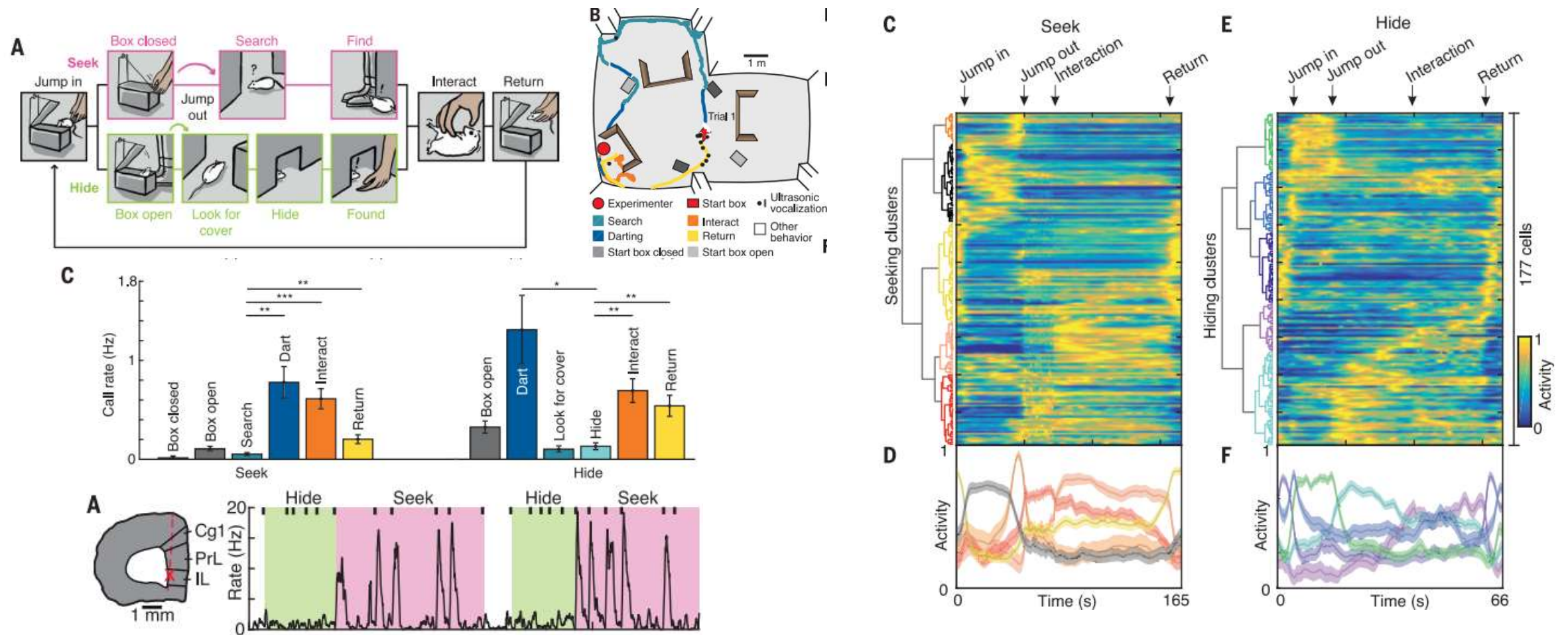
(Stephen M. Siviý. *Behaviour*. 2016.)

Some types of playful behaviors are produced through learning

Learning-style play:



Neuronal correlates of hide-and-seek in rat medial prefrontal cortex



(Annika Stefanie Reinhold. et.al . *Science*. 2019.)

Take home message

- Criteria for play-like behavior require the activity to be (1) of no immediate relevance for survival; (2) voluntary, intentional, and rewarding; (3) non-ethotypical; (4) repeated, yet unstereotyped; and (5) free from stress.
- The role of play is most prevalent in juveniles, with many of the benefits of play being manifested through developmental processes, but play can also serve a function in adulthood.
- Play is a prevalent animal behavior that appears to be an adaptation to the challenges of a dynamic social and ecological environment.

PART II: How do animals benefit from play behavior?

(Influence and consequences)

—CJ

土拨鼠“打架”



看见活的土拨鼠打架了，还是在马路中间

In wild populations, natural selection winnows out any behaviour that is more costly than beneficial

How do animals benefit from play behavior?

- **Evolutionary and Developmental Benefits**

Motor Skills

Reduction of Aggression

Sexual behaviour

Brain development and cognitive flexibility

Social bonding

Cooperation

Life span

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- **Neurobiological Mechanisms**

Opioids

Cannabinoids

Dopamine

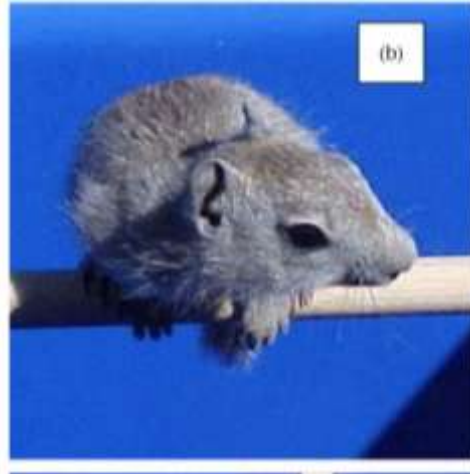
Noradrenaline

Prefrontal cortex (PFC)

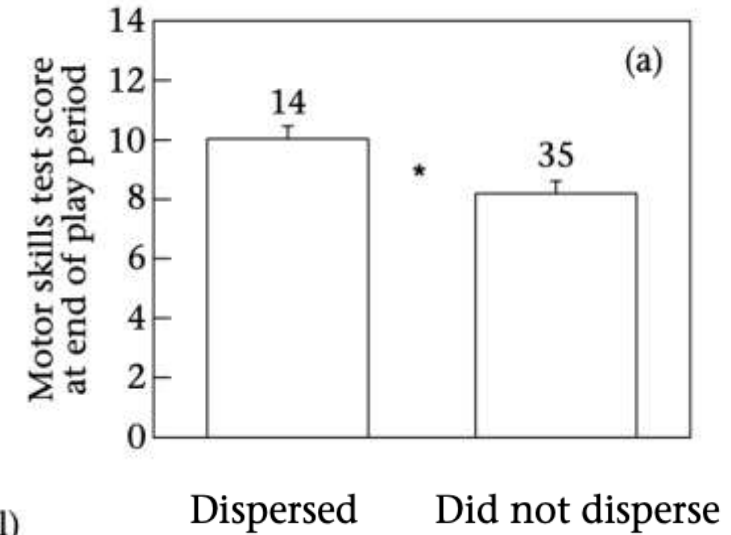
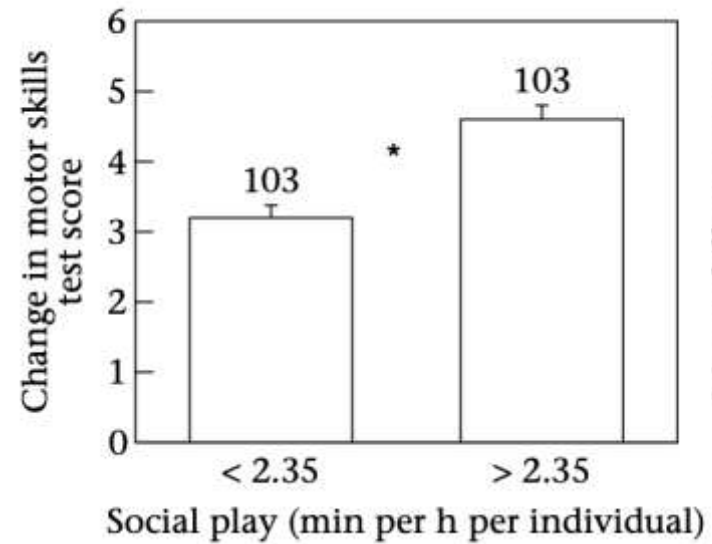
Striatum

Nucleus accumbens (NAc)

Motor Skills

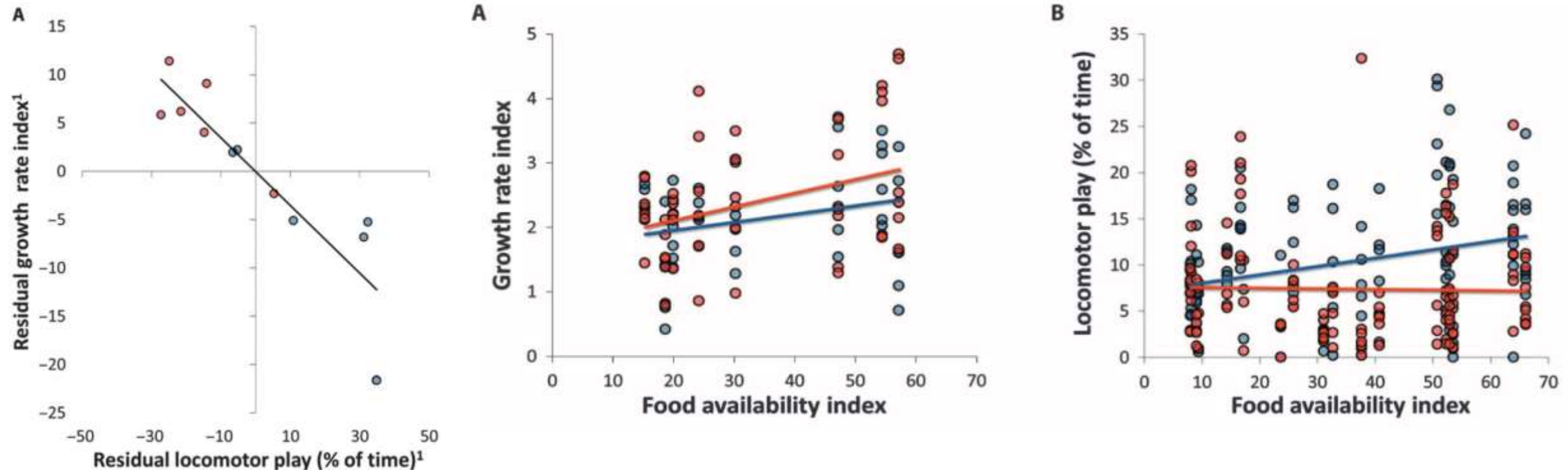


- (a) hanging
- (b) perching
- (c) balancing skills



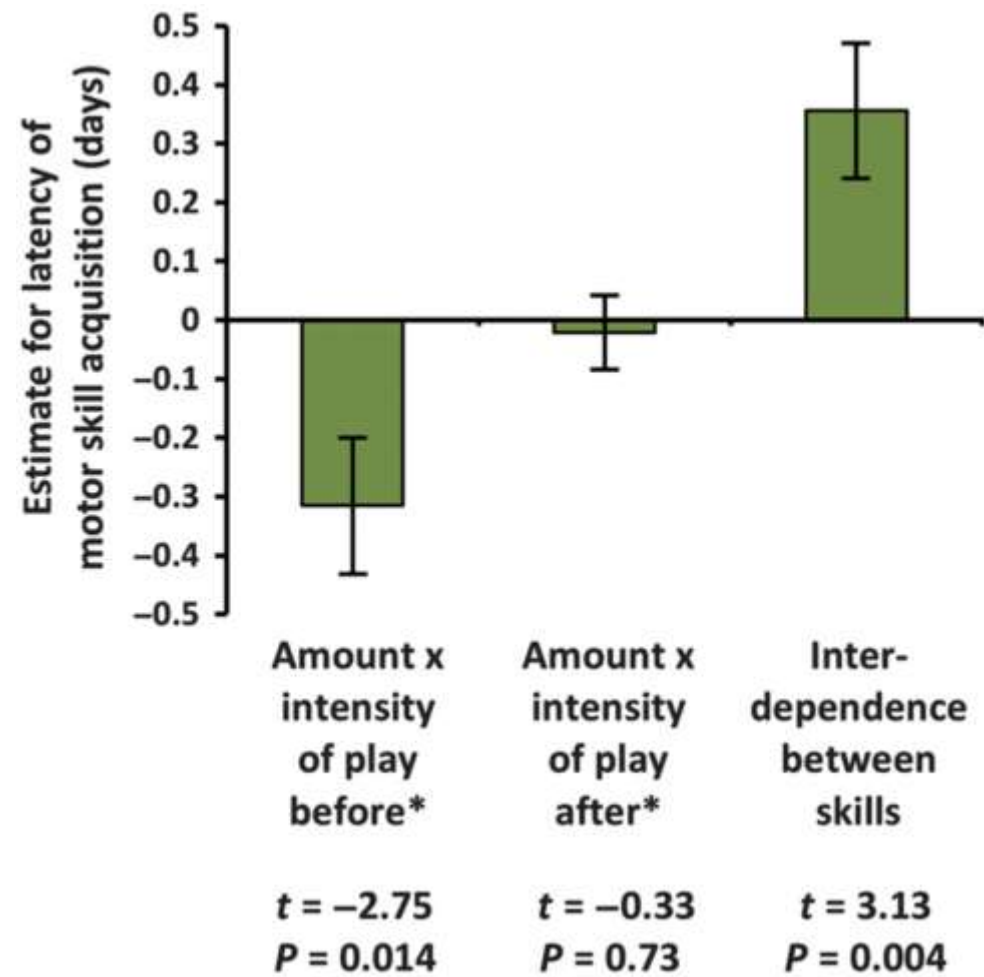
Locomotor play drives motor skill acquisition at the expense of growth: A life history trade-off

[Andreas Berghänel](#)^{1,*}, [Oliver Schülke](#)^{1,†}, [Julia Ostner](#)^{1,2,†}



Locomotor play drives motor skill acquisition at the expense of growth: A life history trade-off

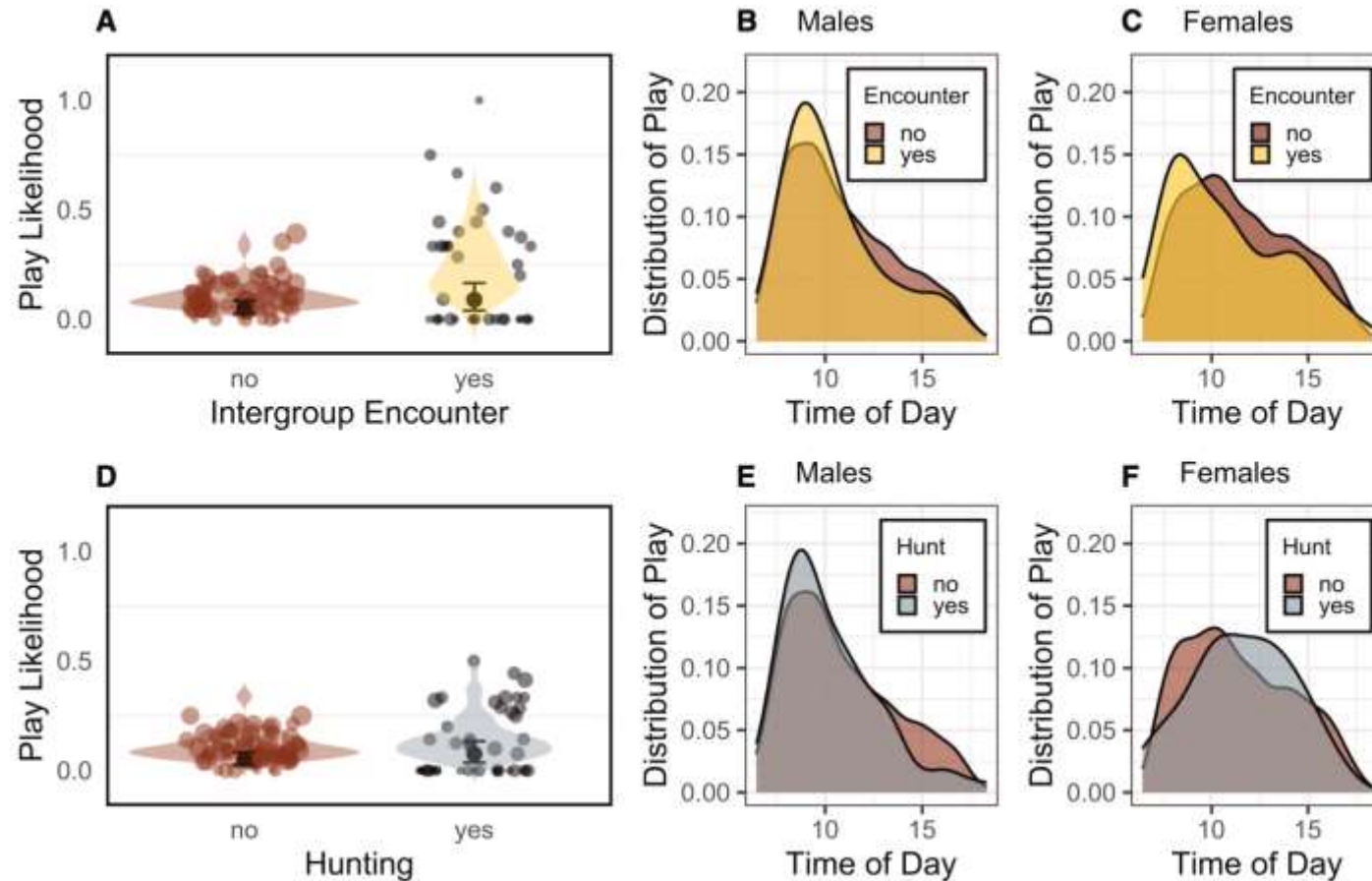
Andreas Berghänel^{1,*}, Oliver Schülke^{1,†}, Julia Ostner^{1,2,†}



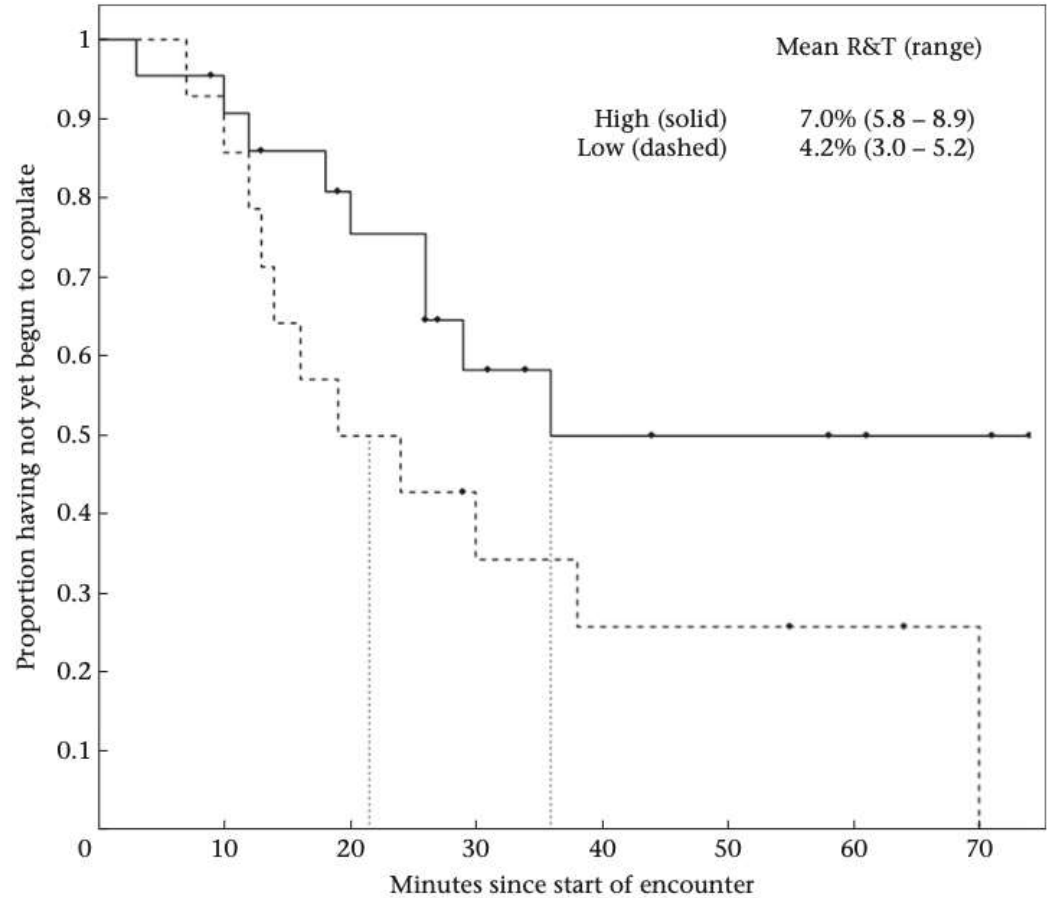
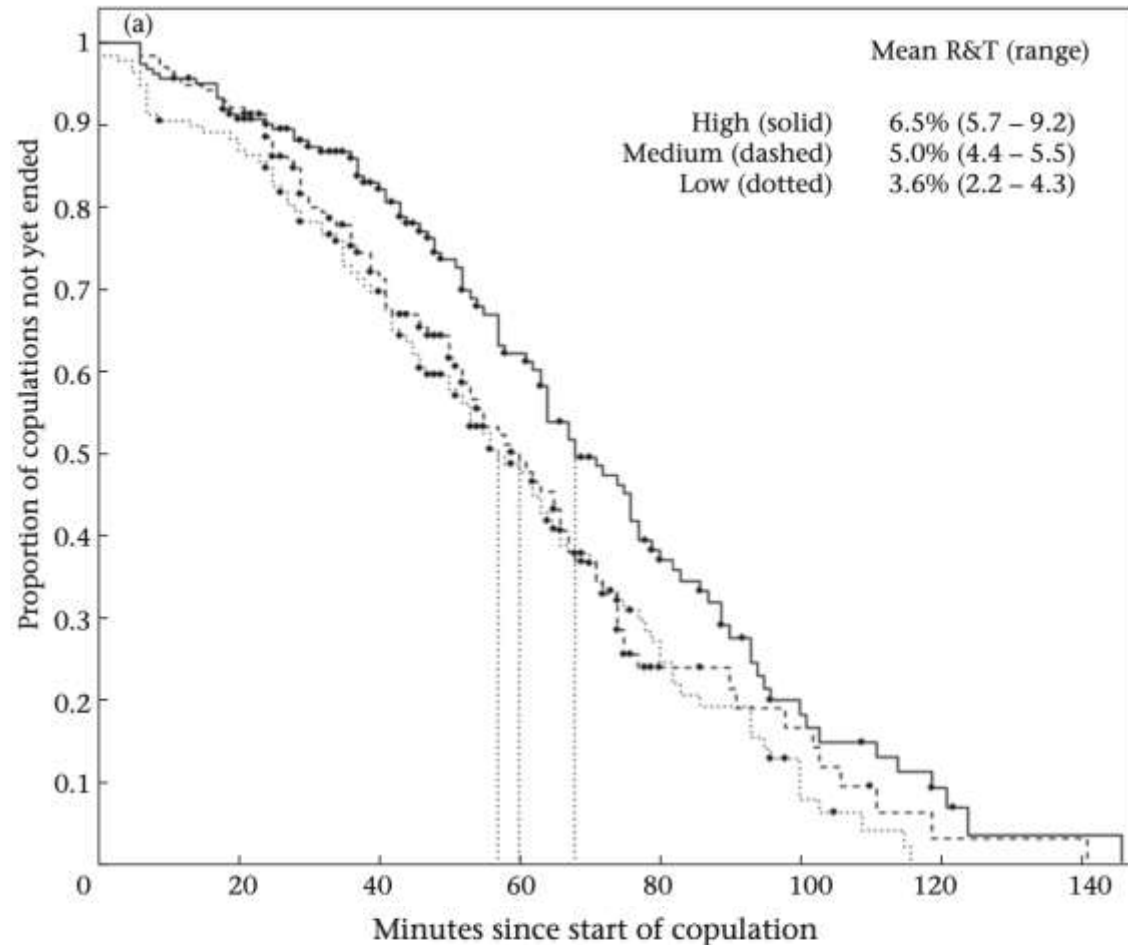
Report

Social play fosters cooperation in wild adult chimpanzees

Liran Samuni,^{1,2,5,8,*} Alexander Mielke,^{3,6} Catherine Crockford,^{2,4,7} and Roman M. Wittig^{2,4,7}



Sexual behaviour

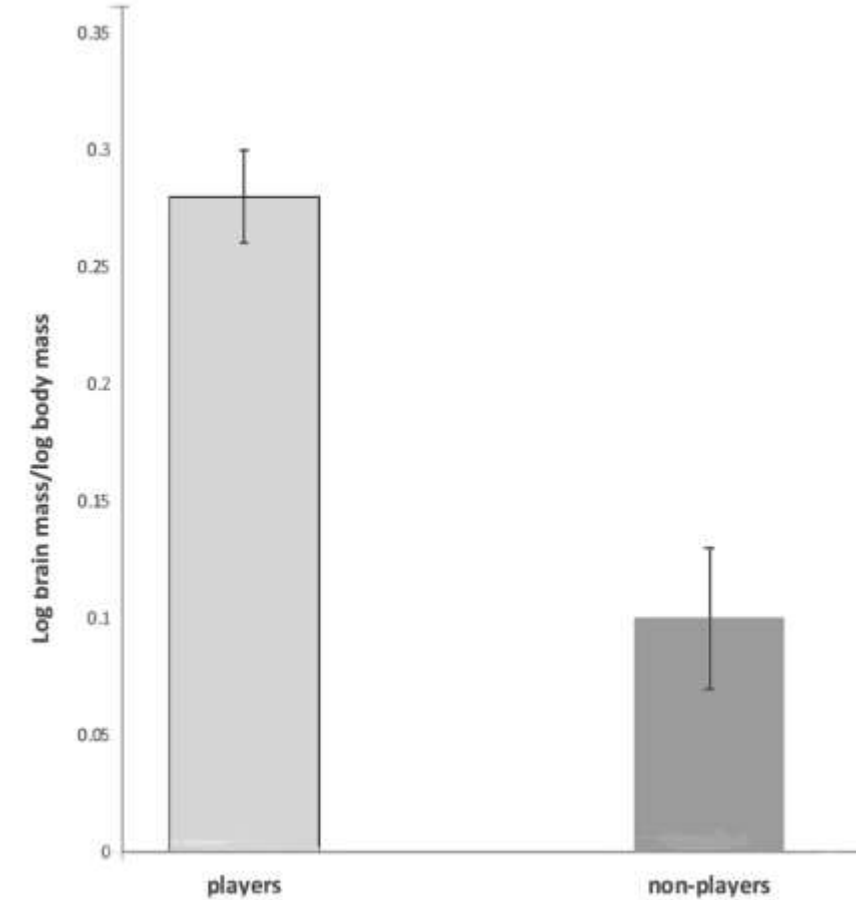
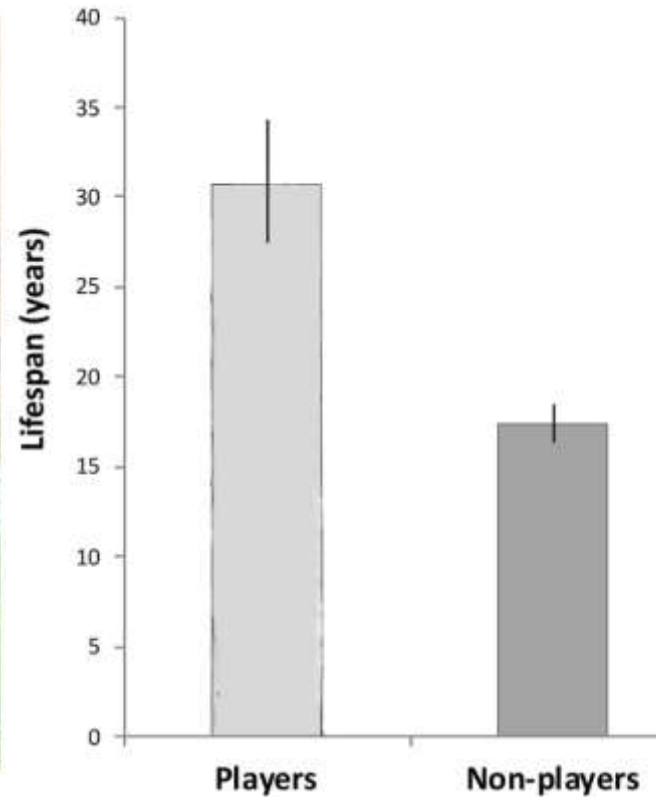


Frequent juvenile R&T (rough-and-tumble play) predicted long-lasting copulations in adult males and longer latencies to copulate in adult females.

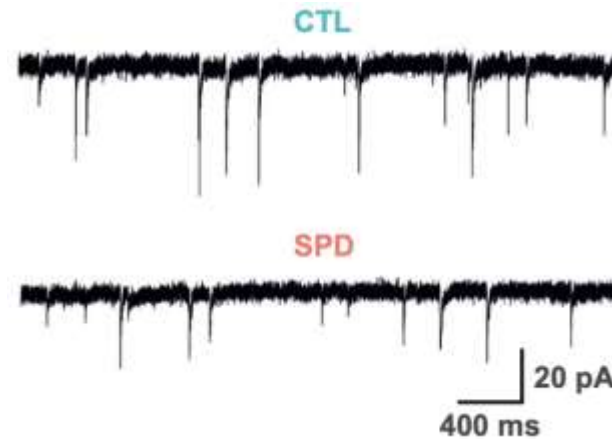
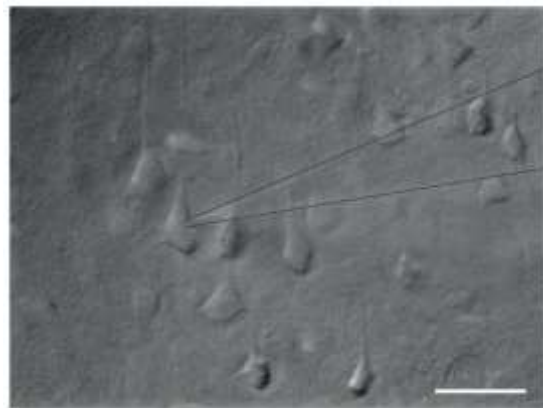
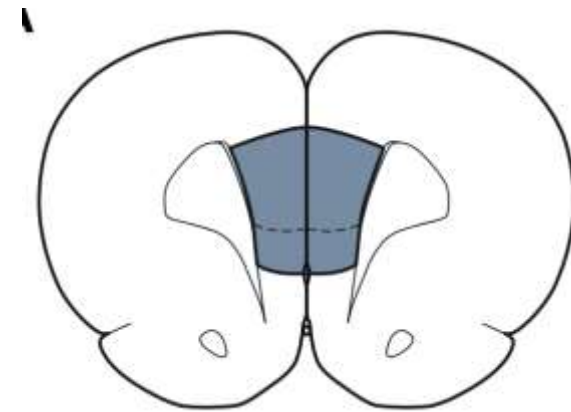
OPEN

Play behaviour, not tool using, relates to brain mass in a sample of birds

Gisela Kaplan

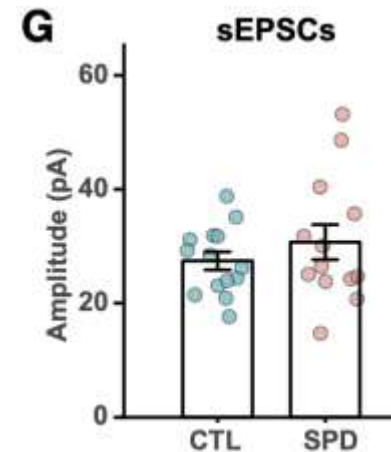
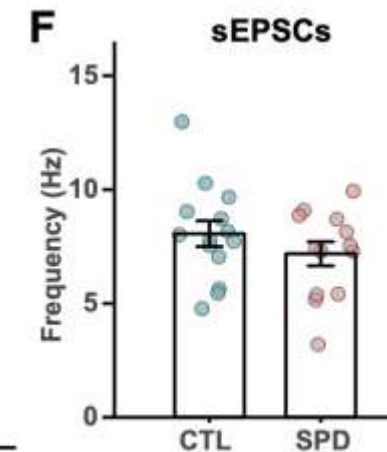
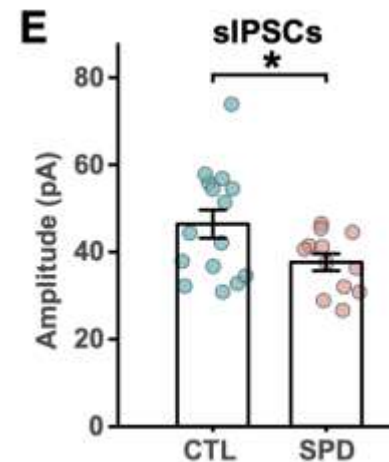
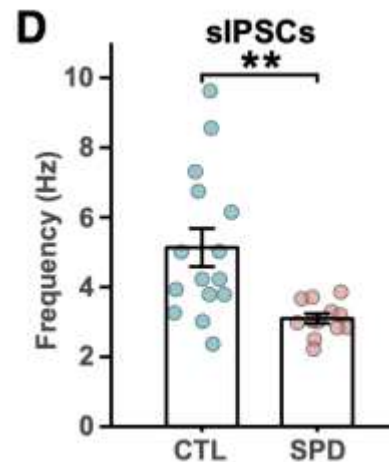


Social Play Behavior Is Critical for the Development of Prefrontal Inhibitory Synapses and Cognitive Flexibility in Rats



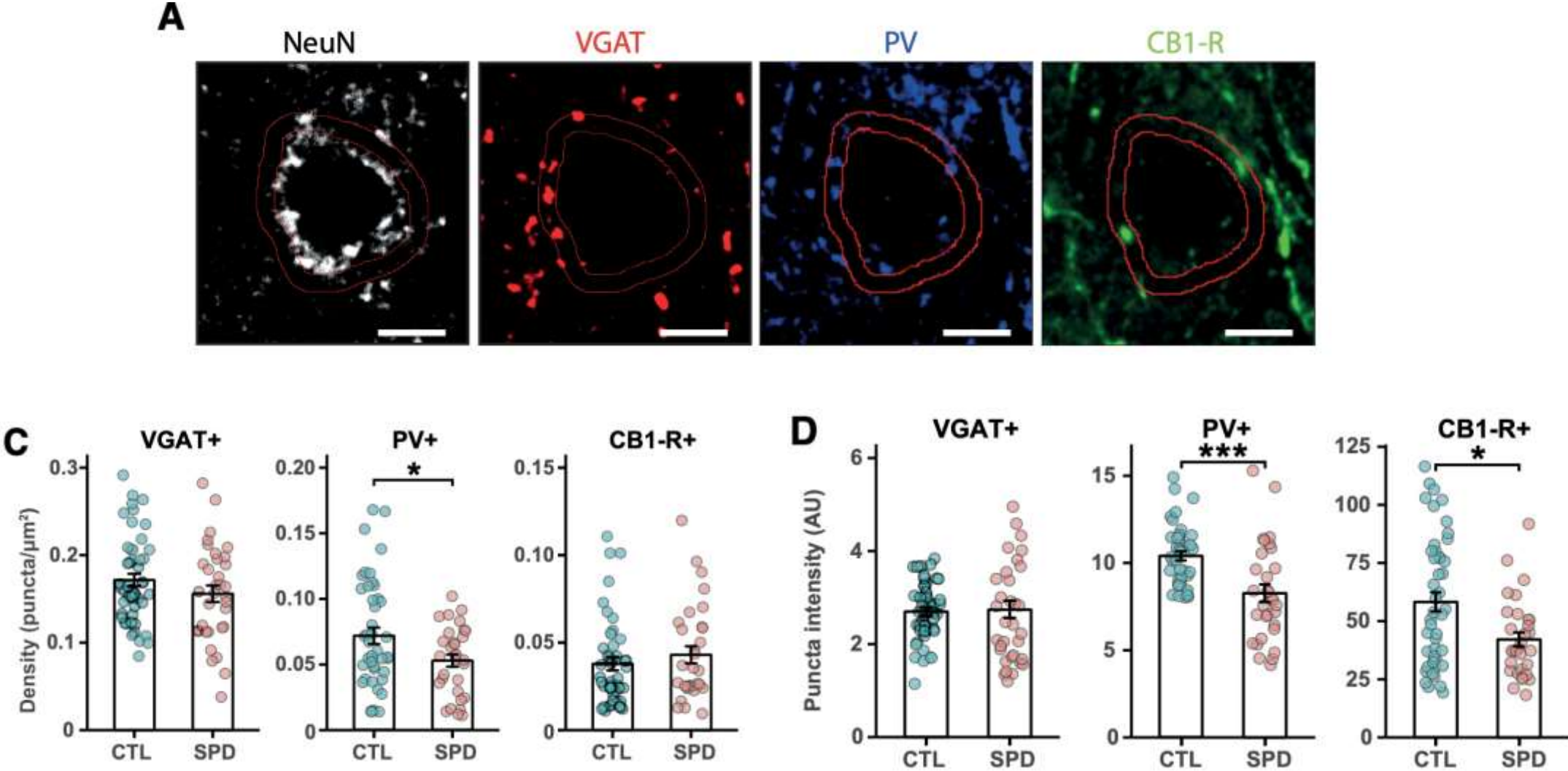
CTL: control

SPD: social play deprived

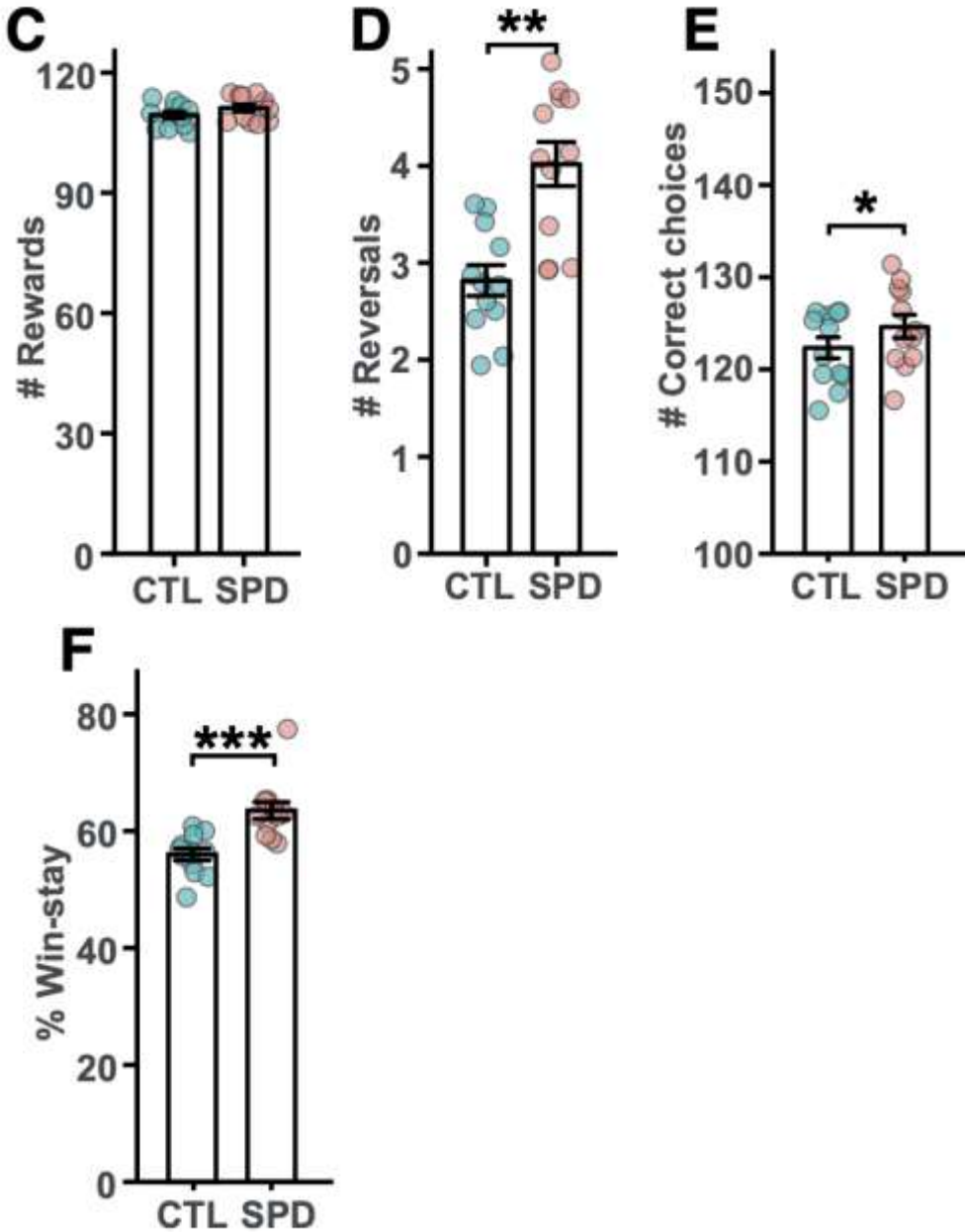
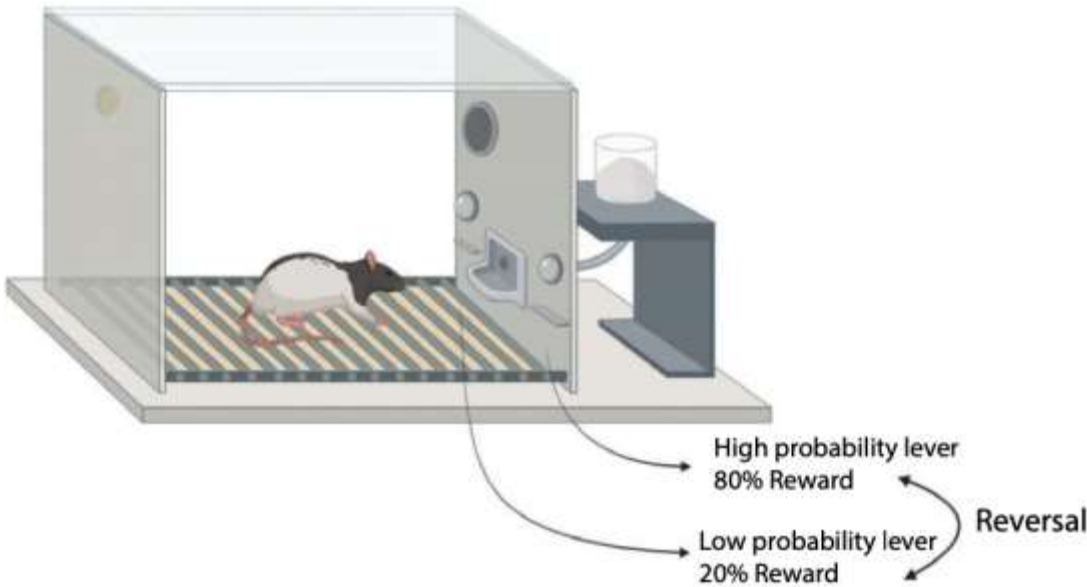


Brain development and cognitive flexibility

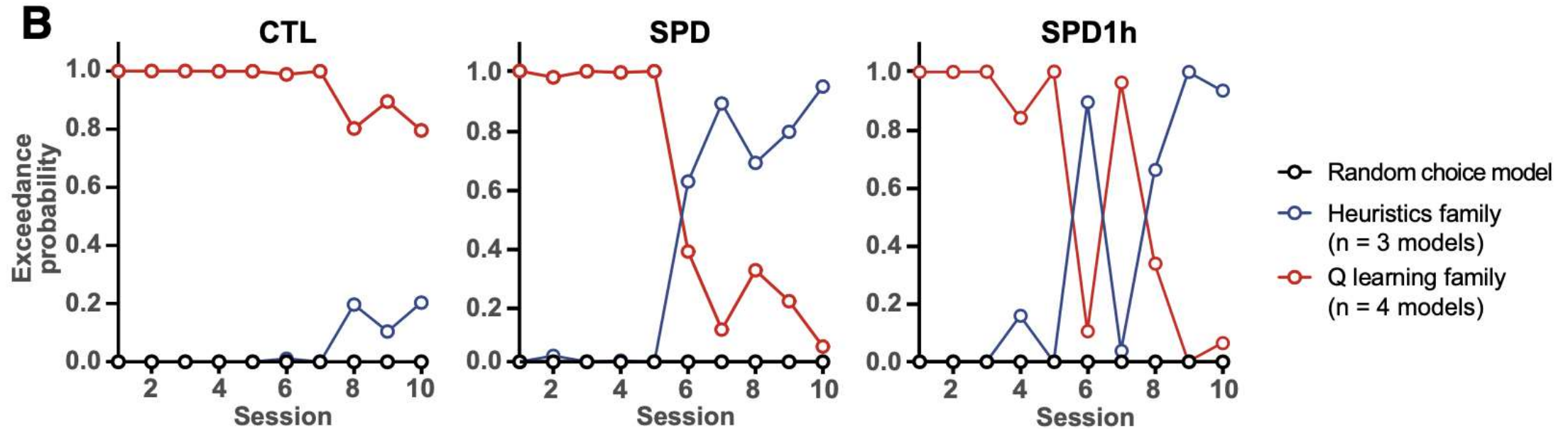
Reduction in perisomatic inhibitory synapses after SPD



Brain development and cognitive flexibility



Brain development and cognitive flexibility



Heuristics Family (启发式策略)：依赖简单规则而非复杂计算的决策方式，依赖基底神经节习惯系统类似策略简化见于：精神分裂症。ADHD，前额叶损伤患者。

Q learning family：整合多试次历史信息，需要前额叶工作记忆和估值系统。

How do animals benefit from play behavior?

- **Evolutionary and Developmental Benefits**

Motor Skills

Reduction of Aggression

Sexual behaviour

Brain development and cognitive flexibility

Social bonding

Cooperation

Life span

.....

- **Neurobiological Mechanisms**

Opioids

Cannabinoids

Dopamine

Noradrenaline

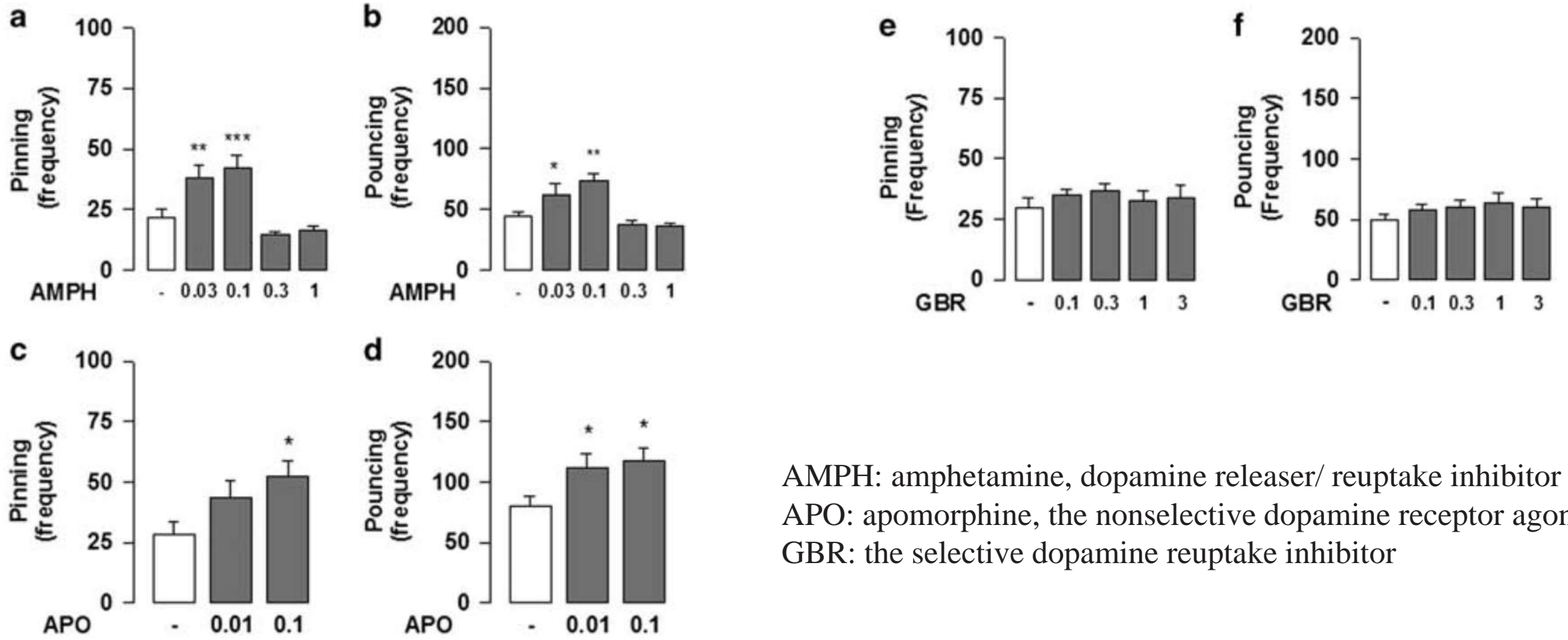
Prefrontal cortex (PFC)

Striatum

Nucleus accumbens (NAc)

Dopamine

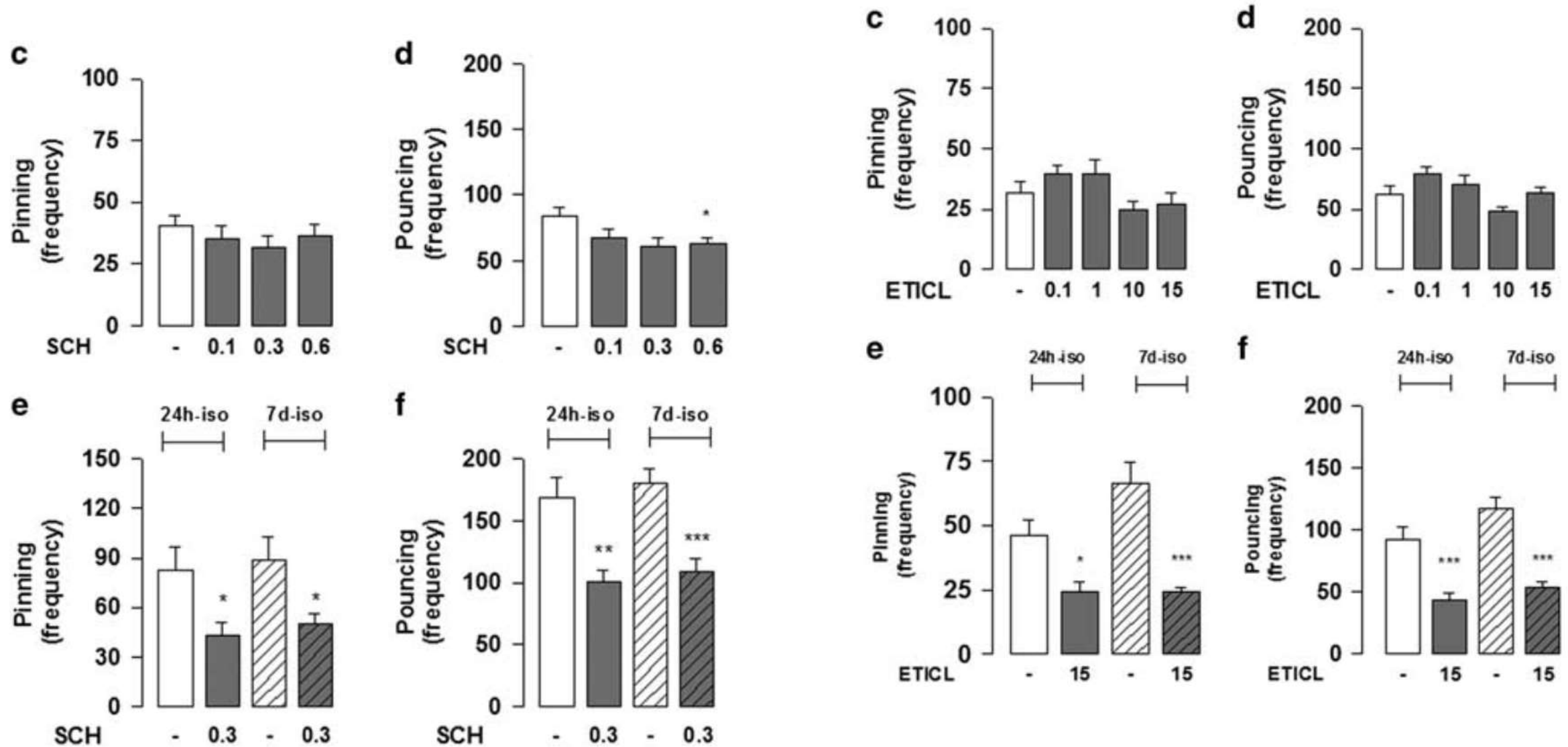
Manipulation of NAc dopaminergic neurotransmission affects social play behavior



AMPH: amphetamine, dopamine releaser/ reuptake inhibitor
APO: apomorphine, the nonselective dopamine receptor agonist
GBR: the selective dopamine reuptake inhibitor

Dopamine

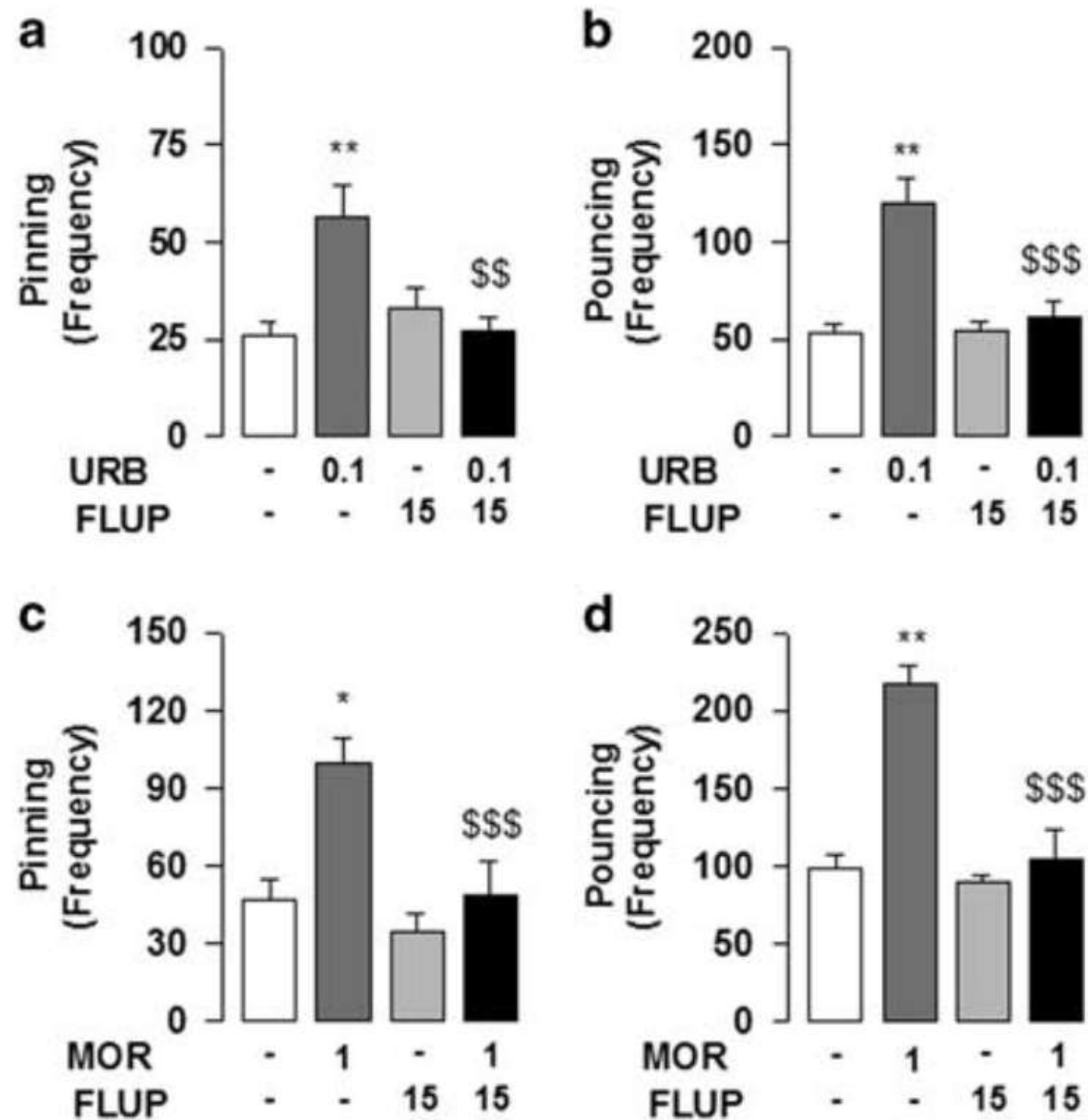
Role of NAc D1 and D2 Dopamine Receptors in Social Play Behavior



SCH: dopamine D1 receptor antagonist
ETICL: dopamine D2 receptor antagonist

Dopamine

Activation of dopamine receptors in the NAc is necessary for endocannabinoid and opioid modulation of social play behavior



FLUP: nonselective dopamine receptor antagonist
URB: anandamide hydrolysis inhibitor
MOR: morphine

Neuron

Microglial Phagocytosis of Newborn Cells Is Induced by Endocannabinoids and Sculpts Sex Differences in Juvenile Rat Social Play

Highlights

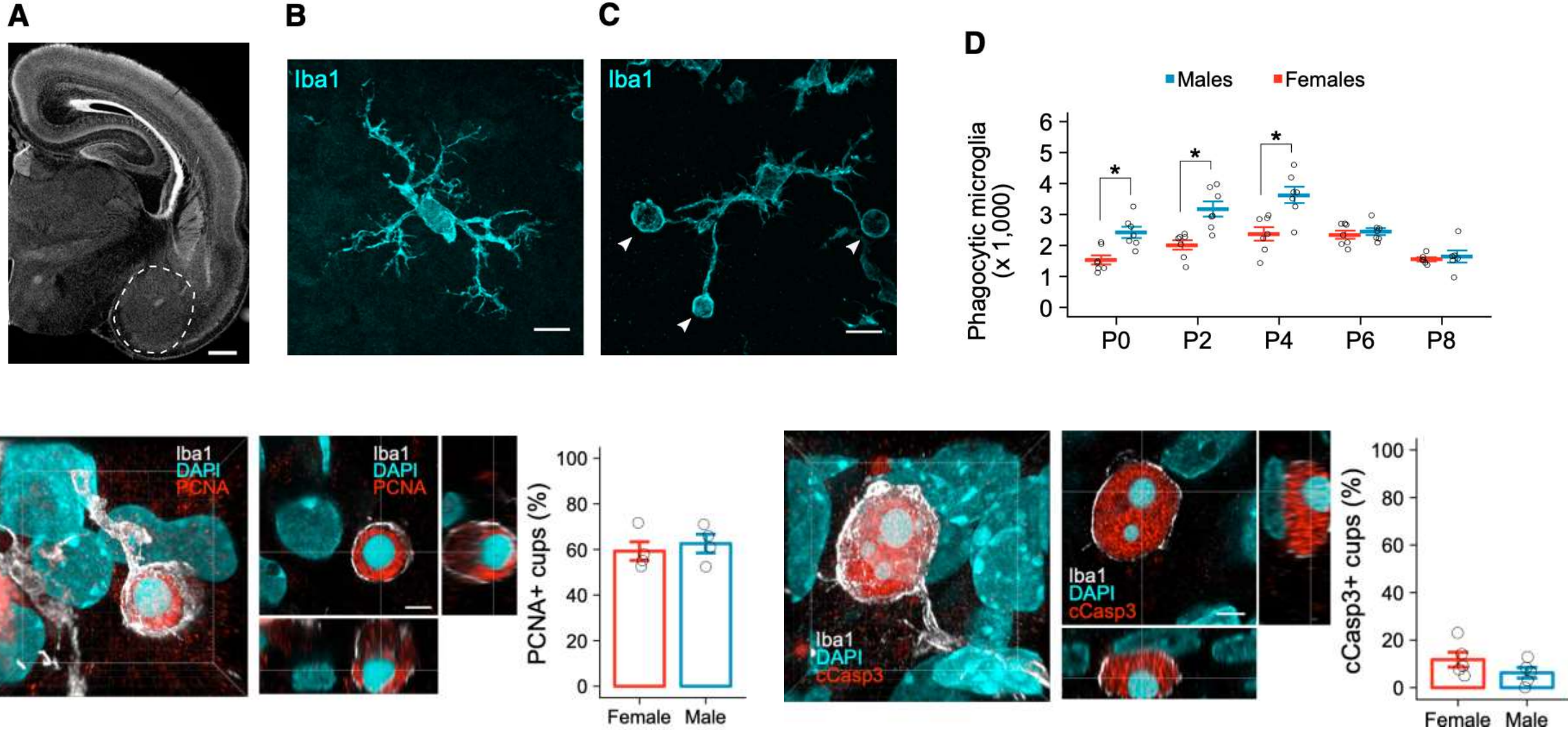
- Microglia are more phagocytic in the male amygdala during neonatal development
- Androgen-induced endocannabinoids increase phagocytosis in males

Authors

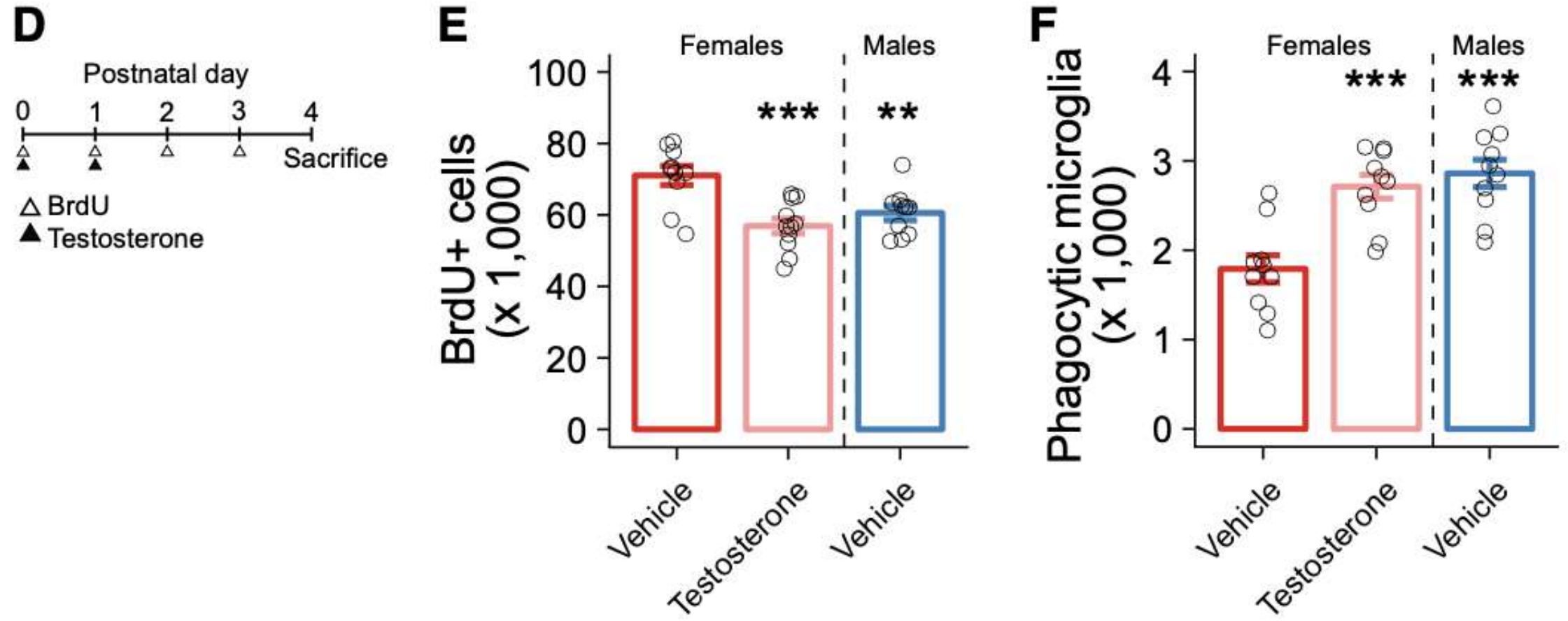
Jonathan W. VanRyzin,
Ashley E. Marquardt,
Kathryn J. Argue, ...,
Sheryl E. Arambula, Matthew N. Hill,
Margaret M. McCarthy

Why do males typically show higher levels of juvenile play behavior compared to females?

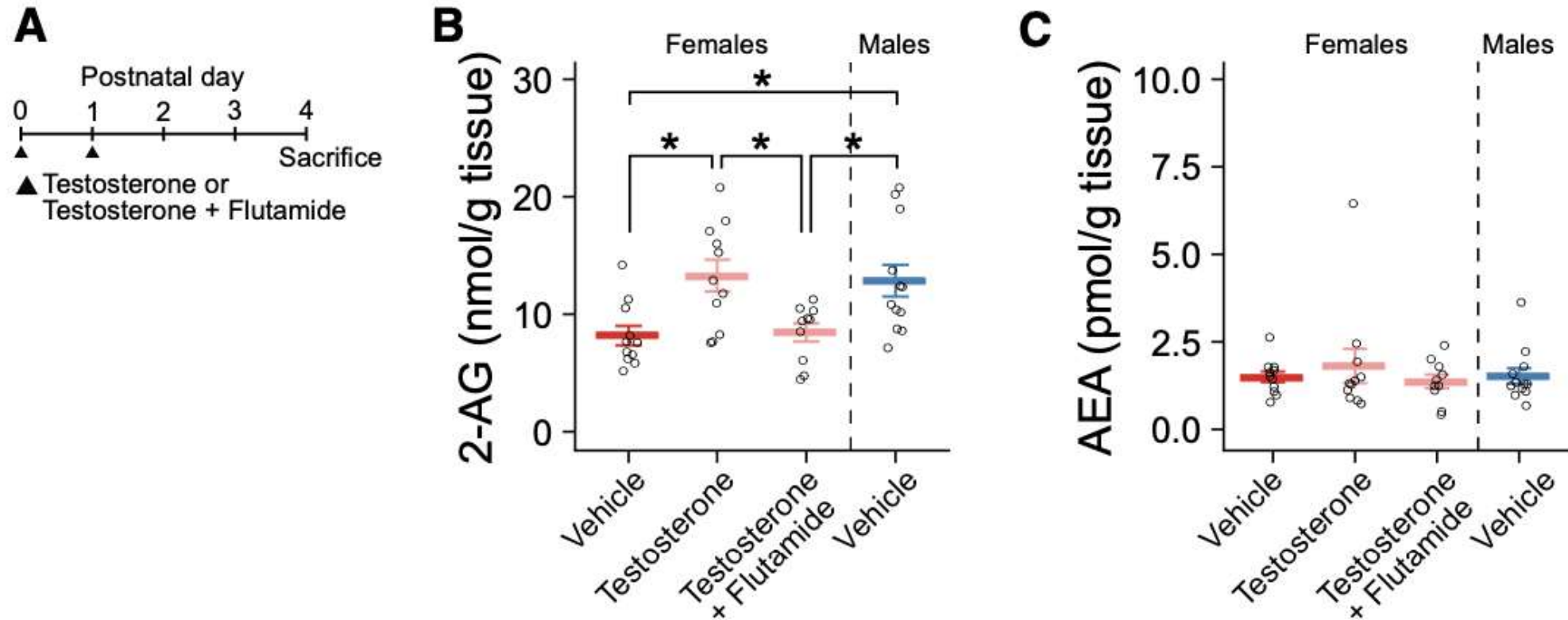
Males Have More Phagocytic Microglia in the Developing Amygdala



Testosterone Masculinizes Newborn Cell Number and Phagocytic Microglia Number in the Developing Amygdala

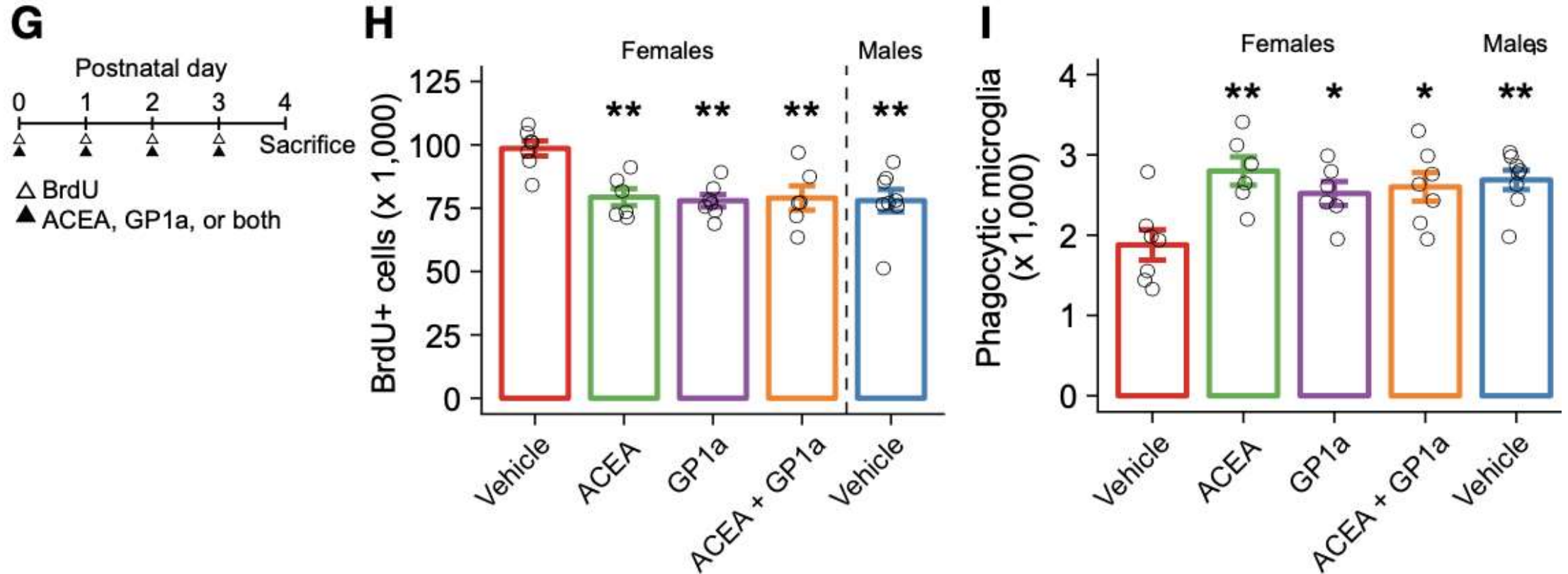


Testosterone Masculinizes Female 2-AG Content



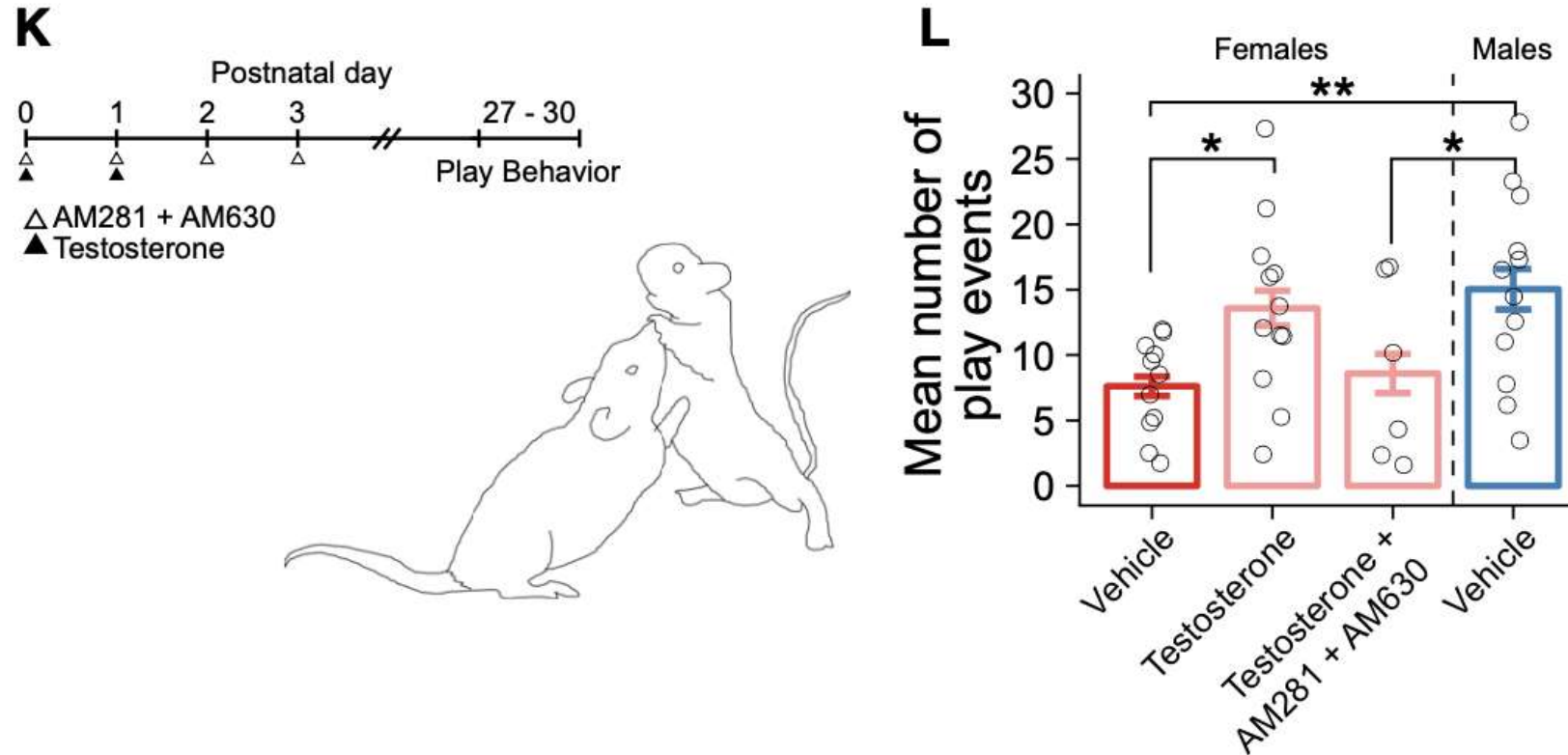
Endocannabinoid: 2-AG , AEA

CB1R/CB2R Agonists Mimic Testosterone's Effects



ACEA: agonist of CB1R
GP1a: agonist of CB2R

Androgen-mediated masculinization of play occurs via increasing endocannabinoids



AM281: antagonist of CB1R
AM630: antagonist of CB2R

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Noradrenaline

Prefrontal cortex (PFC)

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Nucleus accumbens (NAcc)

References

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6. J. W. VanRyzin *et al.*, Microglial Phagocytosis of Newborn Cells Is Induced by Endocannabinoids and Sculpts Sex Differences in Juvenile Rat Social Play. *Neuron* **102**, 435-449 e436 (2019).
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9. A. Bijlsma *et al.*, Social Play Behavior Is Critical for the Development of Prefrontal Inhibitory Synapses and Cognitive Flexibility in Rats. *J Neurosci* **42**, 8716-8728 (2022).
10. L. Samuni, A. Mielke, C. Crockford, R. M. Wittig, Social play fosters cooperation in wild adult chimpanzees. *Curr Biol* **34**, 5839-5845 e5833 (2024).
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PART III: Why do adults play less than juveniles?

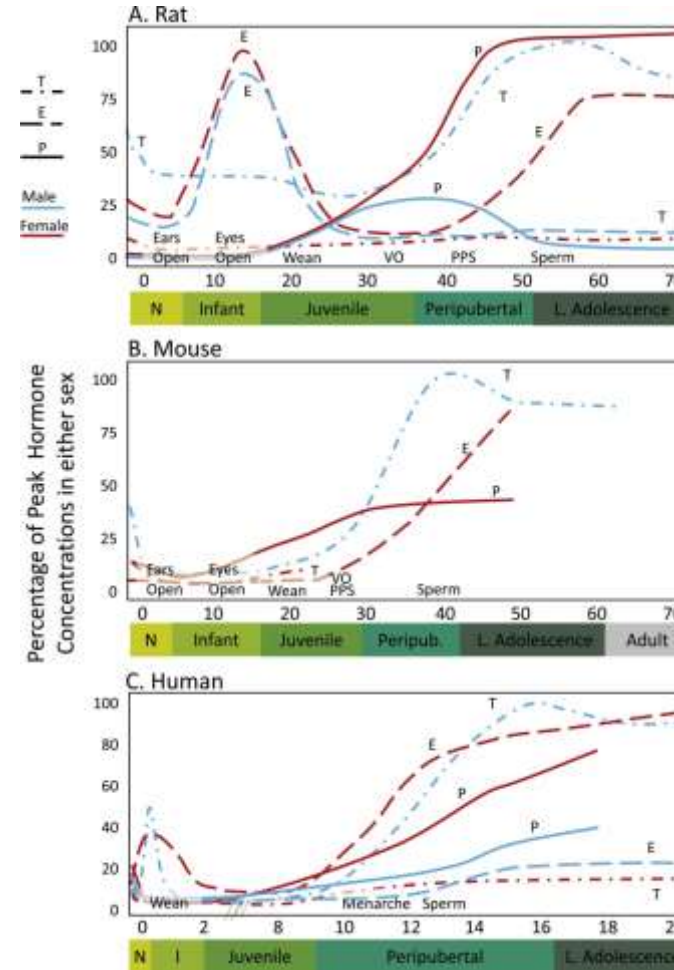
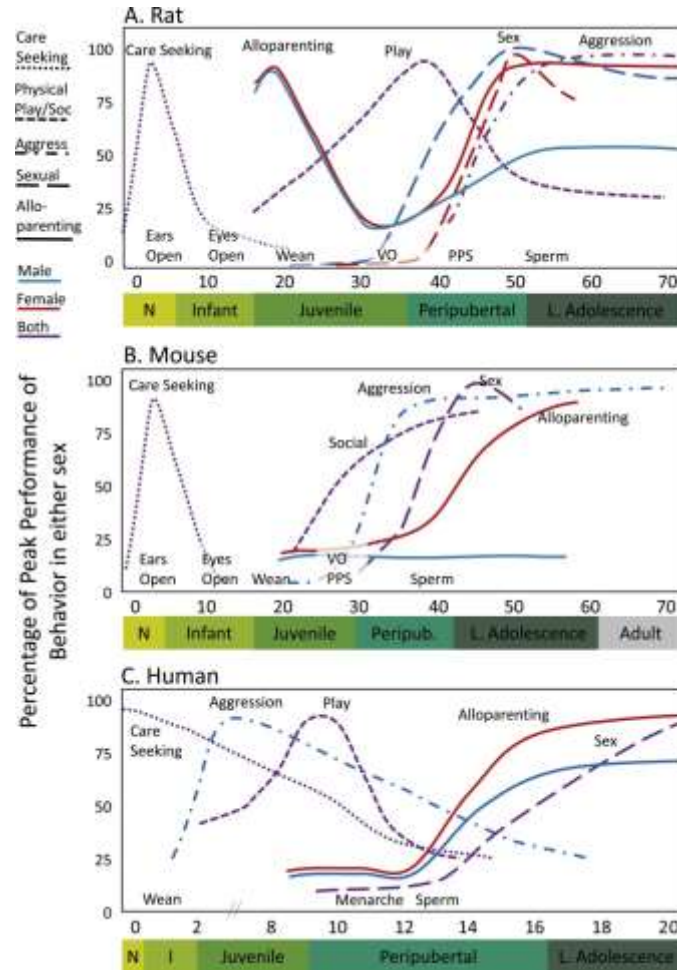
(Regulation and modulation)

—MMZ

Juvenile individuals exhibited higher levels of play behavior



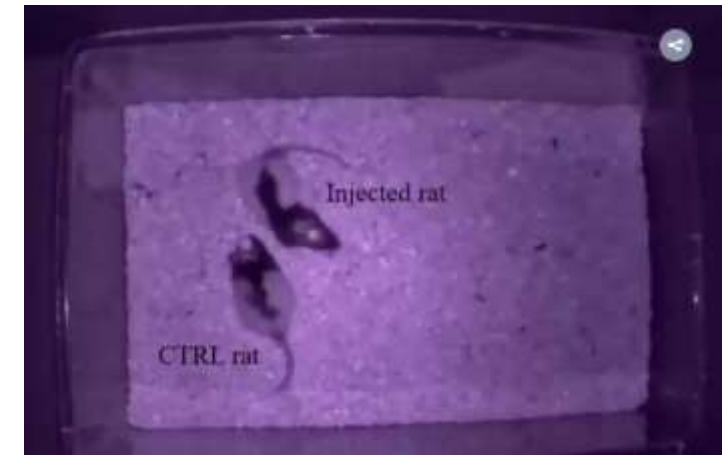
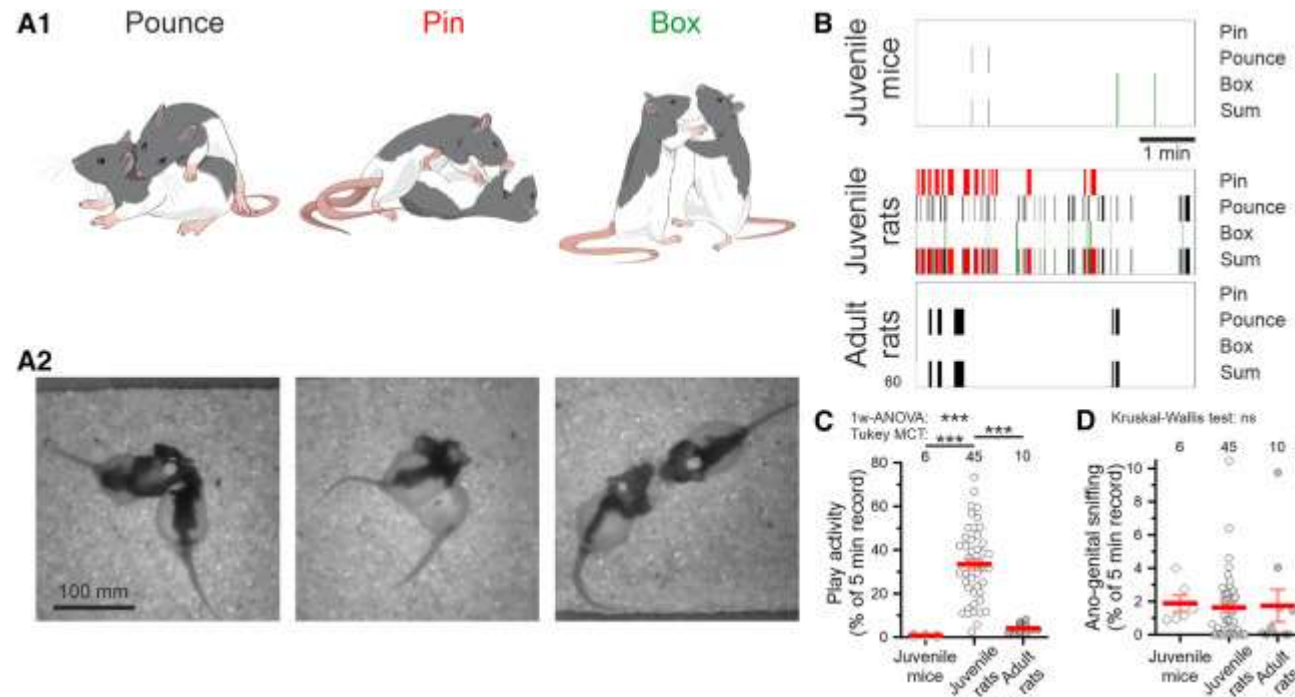
Play behavior peaks during juvenility in both rats and humans



- Why do adults play less than juveniles?
- What additional factors influence play behavior?

- Why do adults play less than juveniles?
- What additional factors influence play behavior?

Rough and tumble play in juvenile rats



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Social play behavior is driven by glycine-dependent mechanisms

[Anton Dvorzhak](#)¹ · [Michael Brecht](#)^{2,3} · [Dietmar Schmitz](#)^{1,2,3,4,5,6,7} 

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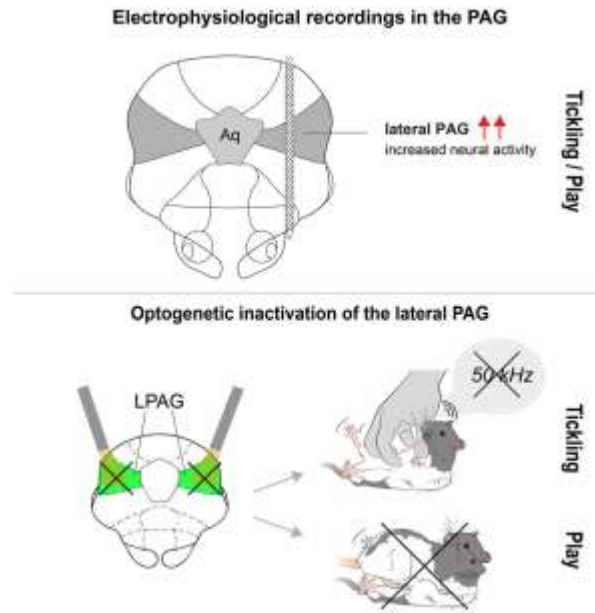


Show Outline

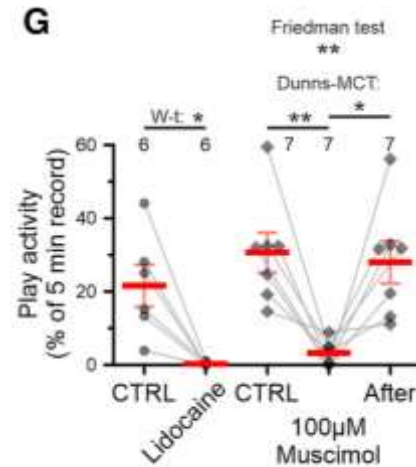
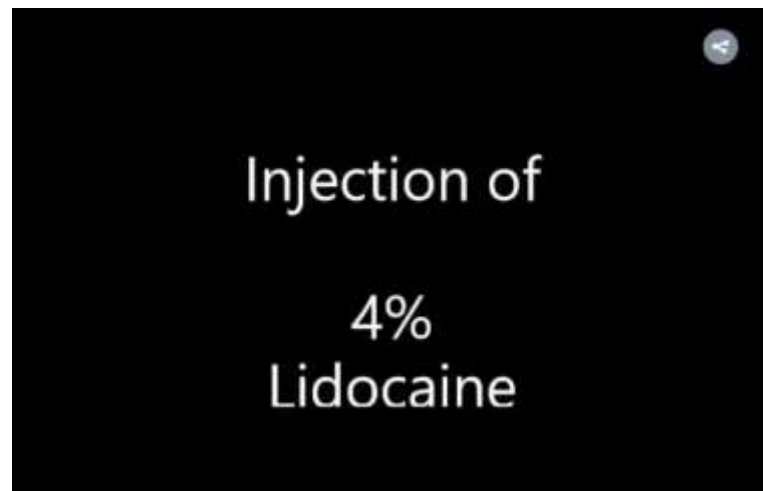
Highlights

- Activity of periaqueductal gray (PAG) neurons is required for social play
- Neuronal activity and glycinergic neurotransmission in PAG decline with age
- Glycine stimulates social play through potentiation of NMDA receptors in PAG
- Age-related social play decrease is partially dependent on glycine decline in PAG

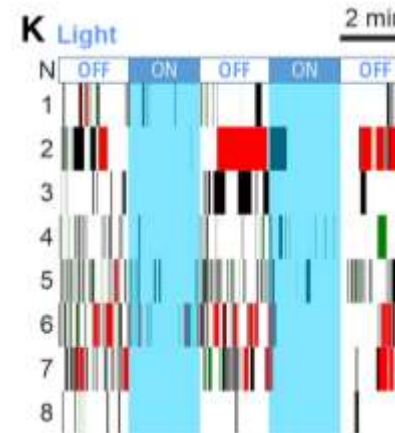
PAG is required for play behavior



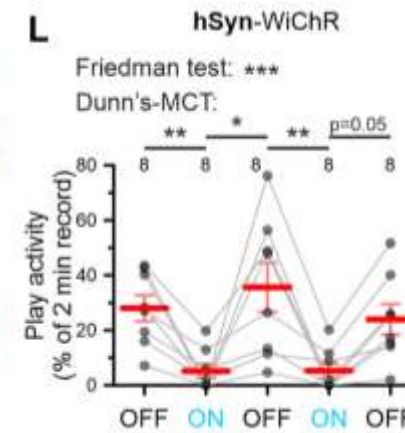
Gloveli N, Simonnet J, Tang W, *Neuron*, 2023.



Lidocaine: Na⁺ channel blocker
Muscimol: agonist of the GABA receptor

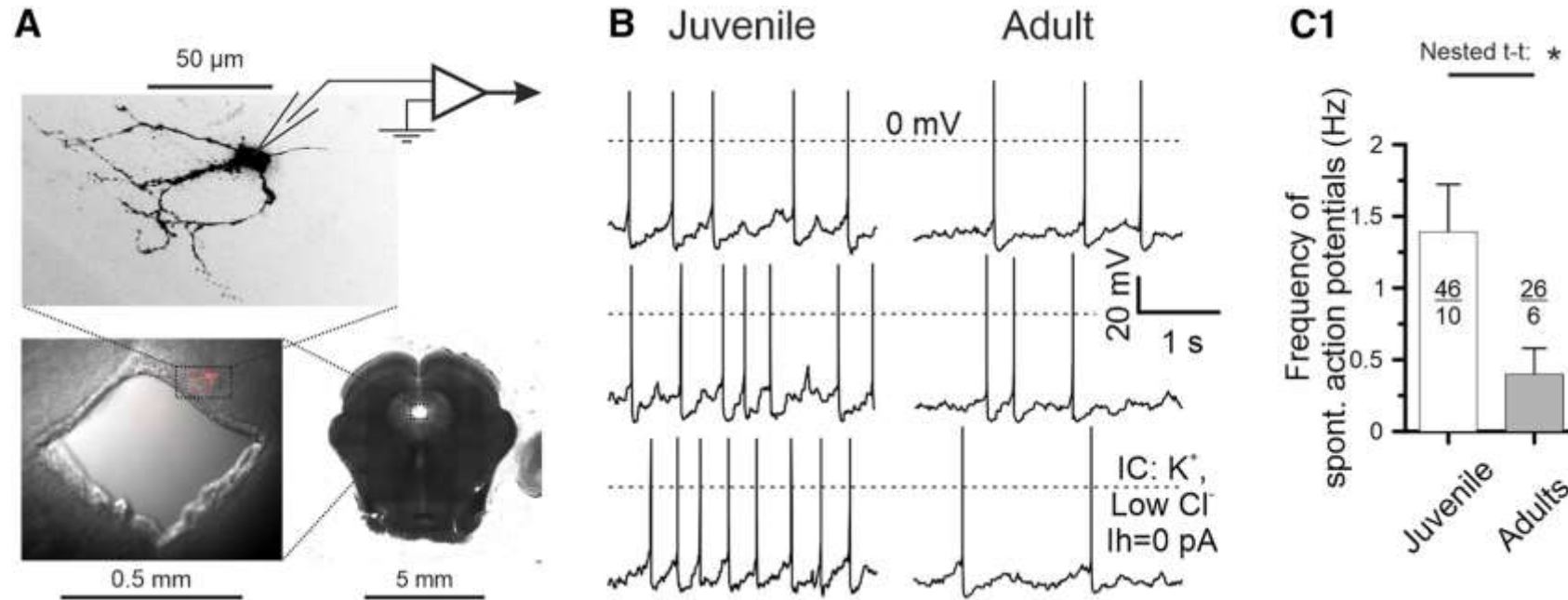


AAV-hSyn-WiChR-mScarlet



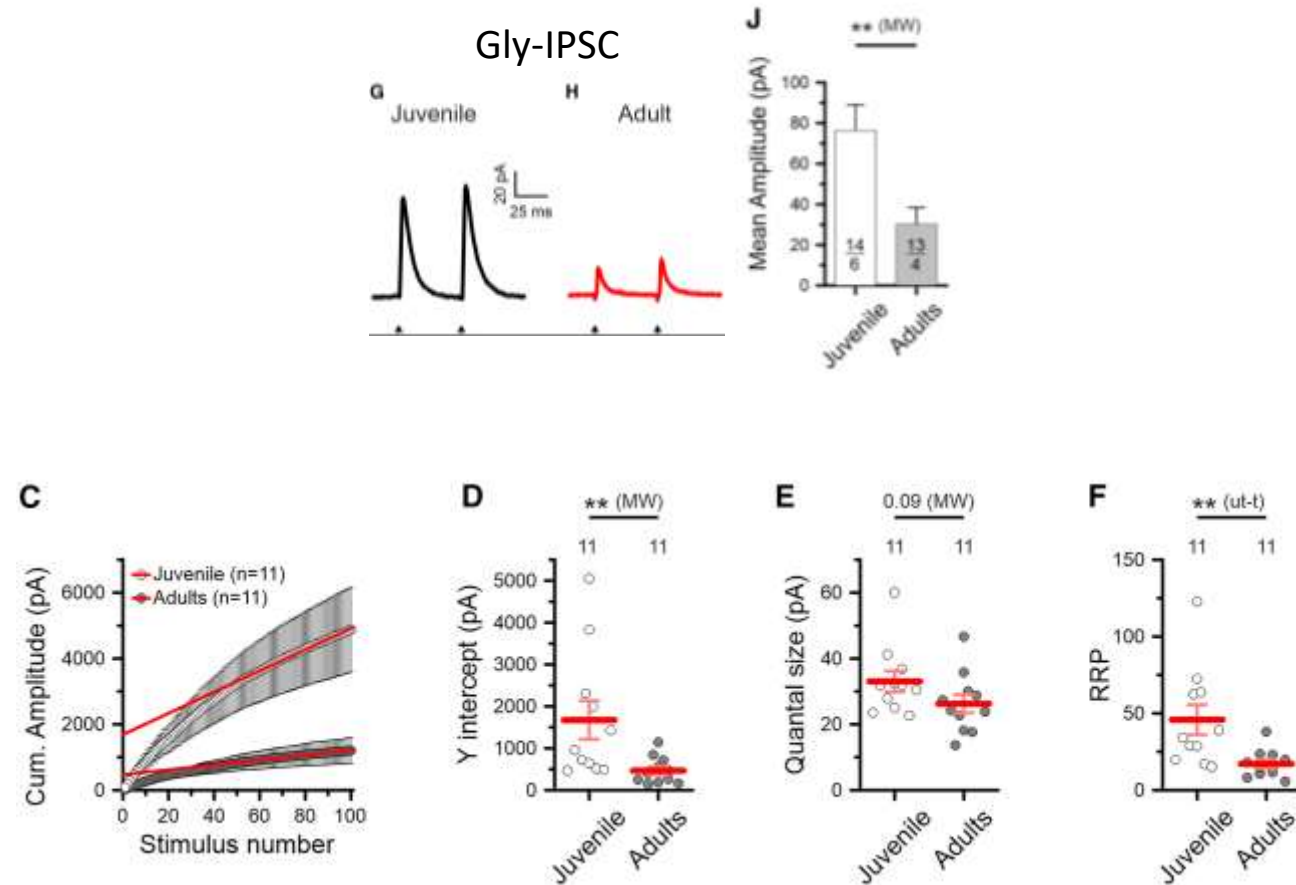
Dvorzhak A, Brecht M, Schmitz D., *Curr Biol.* 2024.

A striking difference in firing properties of neurons of juvenile and adult animals



Dvorzhak A, Brecht M, Schmitz D., *Curr Biol.* 2024.

Adult rats exhibit a smaller glycine RRP (readily releasable pool) in PAG



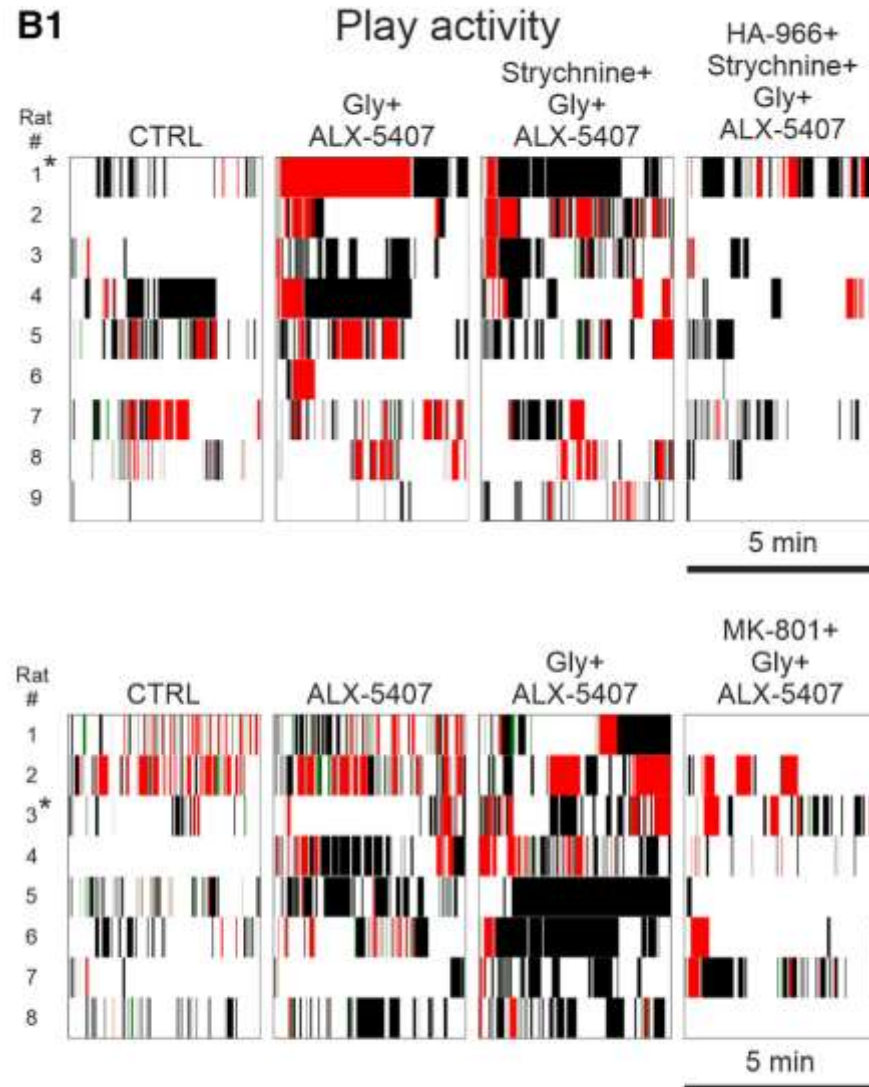
High Gly levels enhance NMDA receptor activity in the PAG of juvenile rats

ALX-5407: glycine transporter 1 (GlyT1) inhibitor

strychnine: glycine receptors antagonist

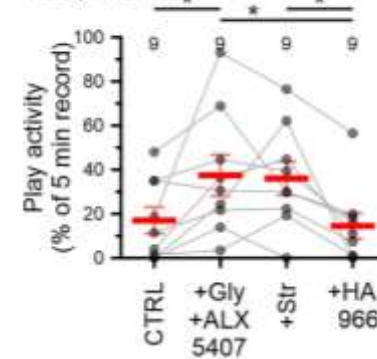
HA-966: the blocker of the glycine-binding site on NMDA receptors

MK-801: NMDA receptor antagonist



1way-RM-ANOVA: **

Tukey-MCT:



A1 Pounce



Pin



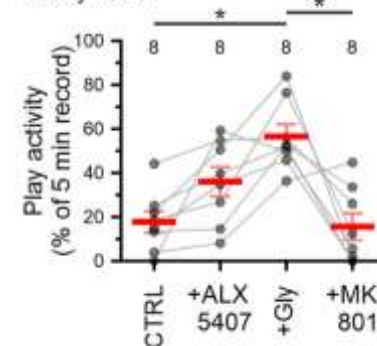
Box



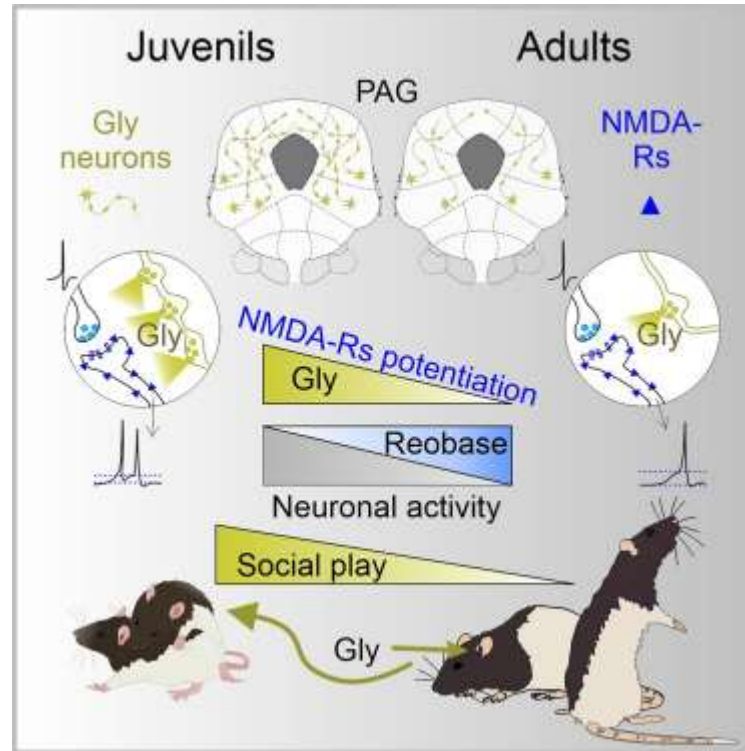
A3

1way-RM-ANOVA: **

Tukey-MCT:

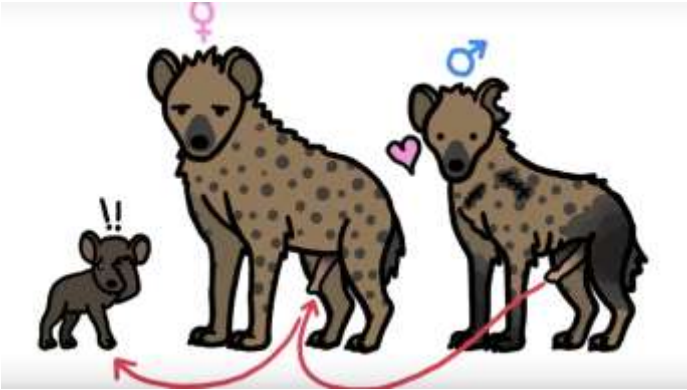
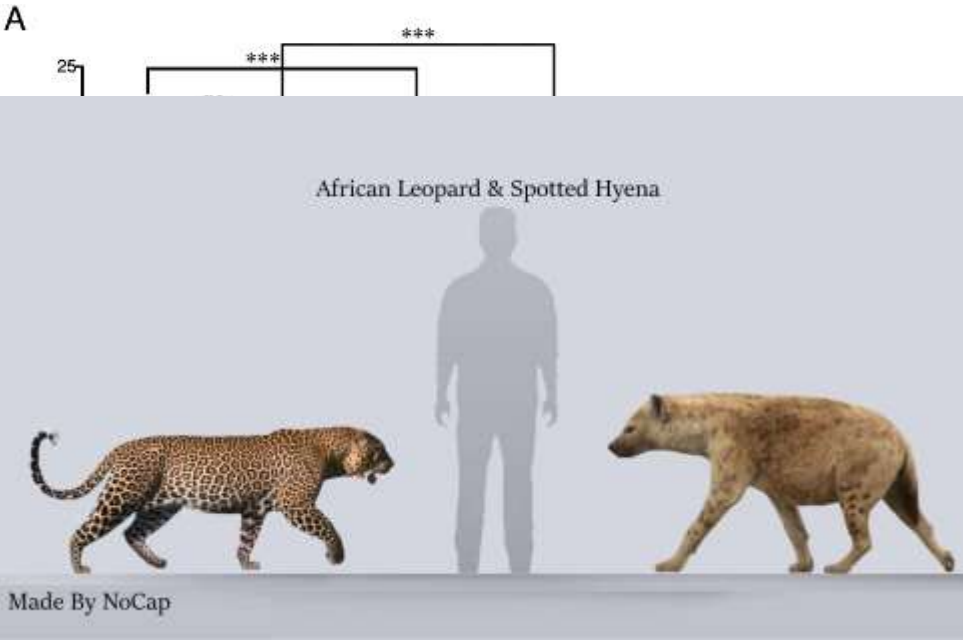


Elevated Gly concentrations in PAG of juvenile mice drive high-intensity play behavior



- Why do adults play less than juveniles?
- What additional factors influence play behavior?

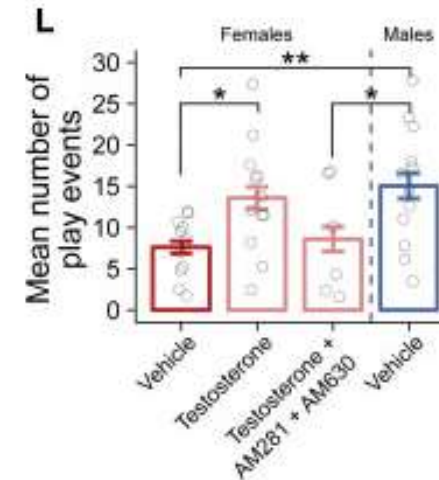
Sex difference of play fighting



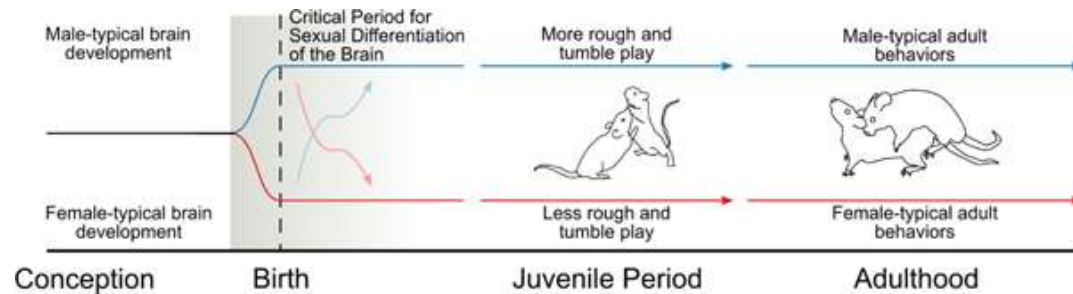
Species Studied	Sex with Higher Play Frequency	References	Additional Notes
<i>Humans</i>	Males	Whiting & Edwards, 1973; DiPietro, 1981; Humphreys & Smith, 1987	
<i>Rats</i>	Males	Poole & Fish, 1976; Oloff & Stewart, 1978; Meaney & Stewart, 1981b	The sex difference is most robust in same-sex dyads and least robust when highly motivated, i.e. preceded by a period of social isolation
<i>Cats (domestic)</i>	Males	Caro, 1981	Males from all-male groups play at higher frequency than females from all-female groups; male play frequency was not influenced by the number of opposite-sex playmates while female play is affected by the number of male playmates
<i>Dogs (domestic)</i>	Males	Pal, 2008; Ward et al., 2008	In mixed-sex dyads, males also engaged in offensive behaviors and self-handicapped more than females (Ward et al., 2008)
<i>Horses (domestic)</i>	Males	Crowell-Davis et al., 1987	
<i>Pigs (domestic)</i>	Males	Dobao et al., 1987; Brown et al., 2018; Weller et al., 2019	
<i>Cattle (domestic)</i>	Males	Reinhardt et al., 1978	Additionally, both sexes prefer to direct play behavior toward male calves
<i>Sheep (domestic)</i>	Males	Sachs & Harris, 1978	
<i>Sheep (wild)</i>	Males	Hass & Jenni, 1993	Male lambs also exhibit a larger repertoire of play behaviors than females
<i>Siberian ibex</i>	Males	Byers, 1980	
<i>Sea lions</i>	Males	Gentry, 1974	Male pups also exhibit a larger repertoire of play behaviors than females
<i>Yellow-bellied marmots</i>	Males	Jamieson & Armitage, 1987; Monclús et al., 2011	Females with larger anogenital distances (i.e. masculinized females) engaged in play more frequently than females with smaller anogenital distances (Monclús et al., 2011)
<i>Belding squirrels</i>	Males	Holekamp et al., 1984	
<i>Rhesus monkeys</i>	Males	Goy & Deputte, 1996	Sex difference in frequency is based on a sex difference in play initiations (males > females)
<i>Squirrel monkeys</i>	Males	Biben, 2010	Male play bouts are also longer than female play bouts
<i>Lowland gorillas</i>	Males	Meder, 1990	
<i>Baboons</i>	Males	Owens, 1975	
<i>Spotted hyenas</i>	Females	Pedersen et al., 1990	Females of this species are dominant to males, are larger than males, and have external genitalia. Speaking to these observations, adult females also have higher levels of circulating testosterone relative to males than is typically seen in female mammals.

The perinatal critical period for sexual differentiation of the brain

Testosterone: main androgen (male sex hormone)
AM281+AM630: antagonists of testosterone



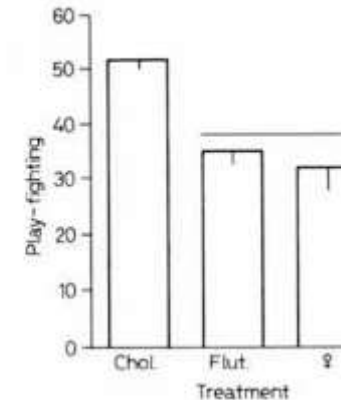
VanRyzin JW, et al., *Neuron*. 2019.



VanRyzin JW, Marquardt AE, McCarthy MM. *Int J Play*, 2020.

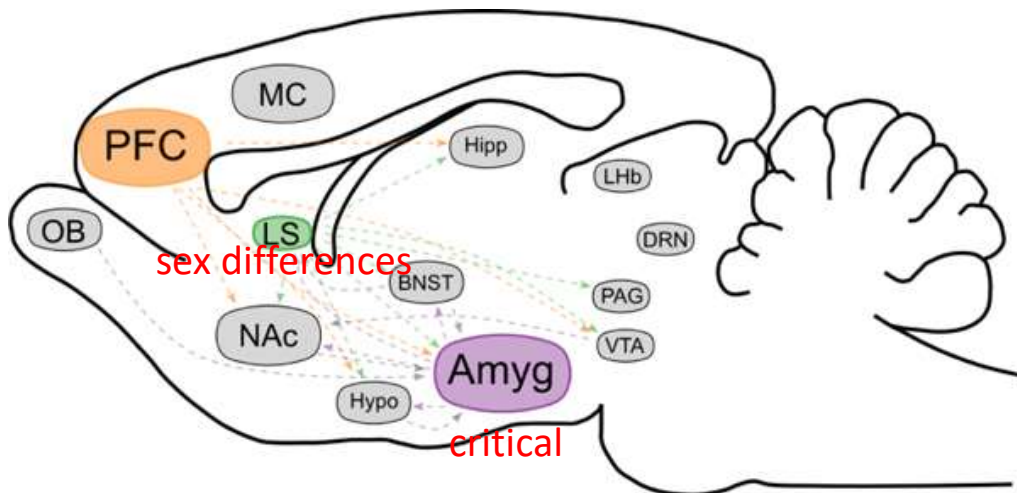
Flutamide: blocker of androgens (male hormones)

Flutamide treatment

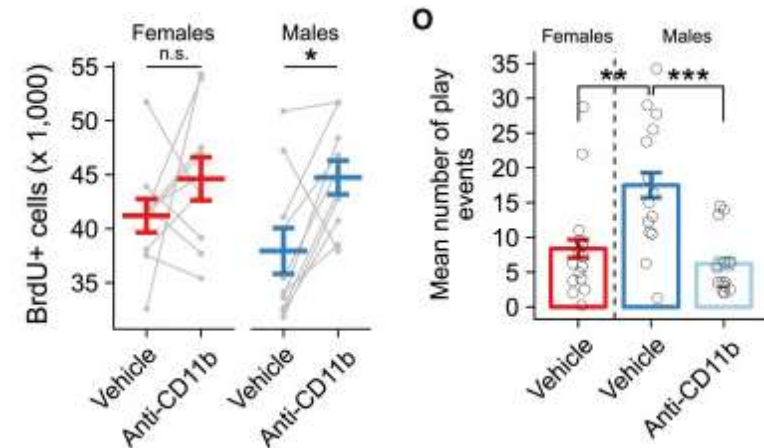


Meaney, et al., *Neuroendocrinology*, 1983.

Distinct Nodes in the Neural Circuitry of Play



VanRyzin JW, Marquardt AE, McCarthy MM. *Int J Play*, 2020.

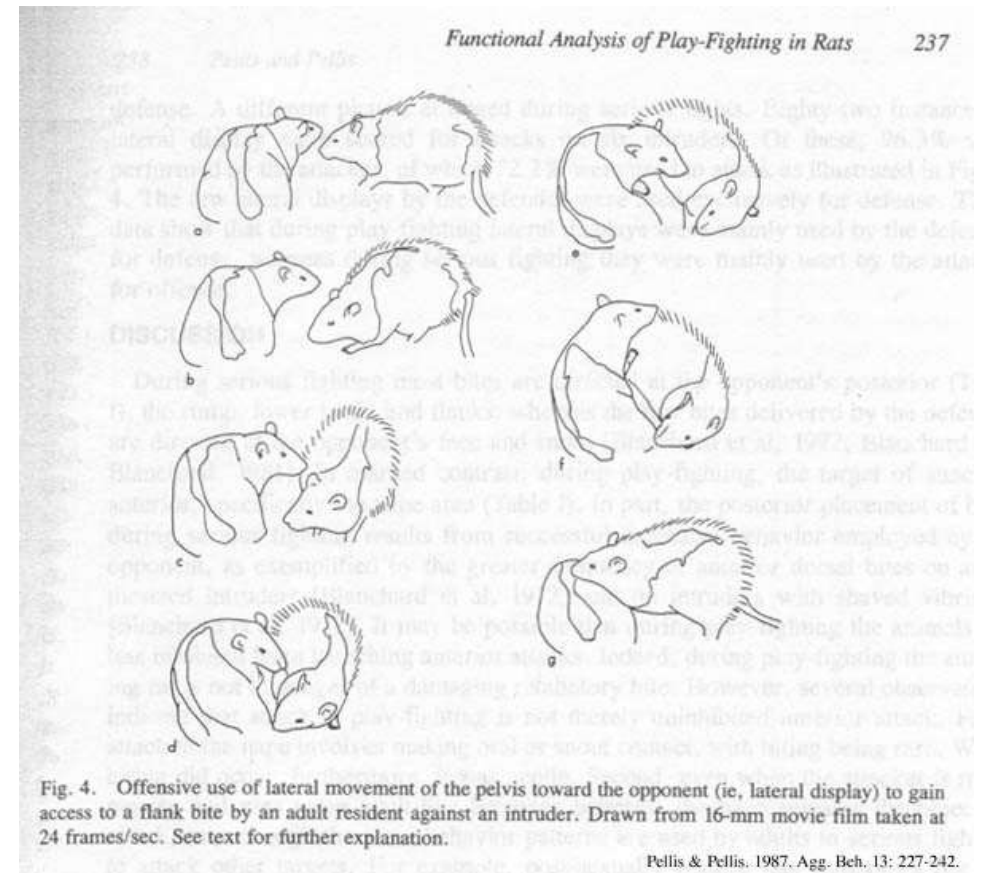
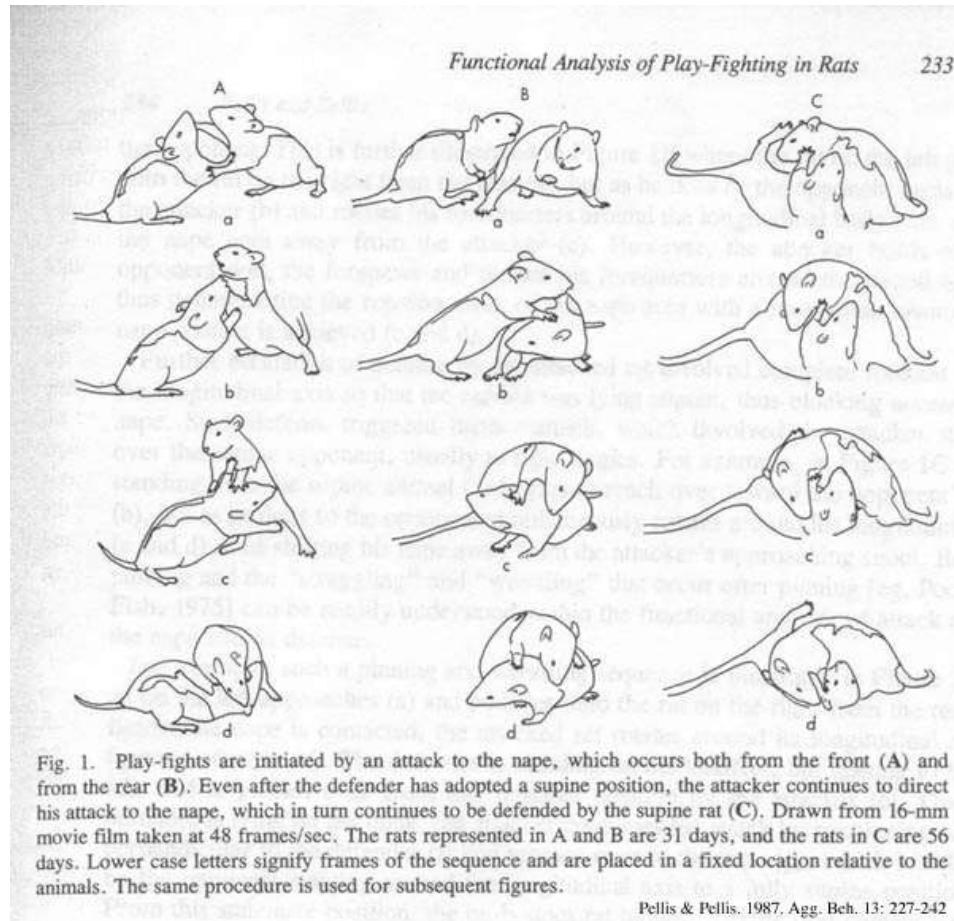


VanRyzin JW, et al., *Neuron*. 2019.

The deviation of win–loss ratios from 50:50 triggers the transition from play to aggression



Playing versus Fighting

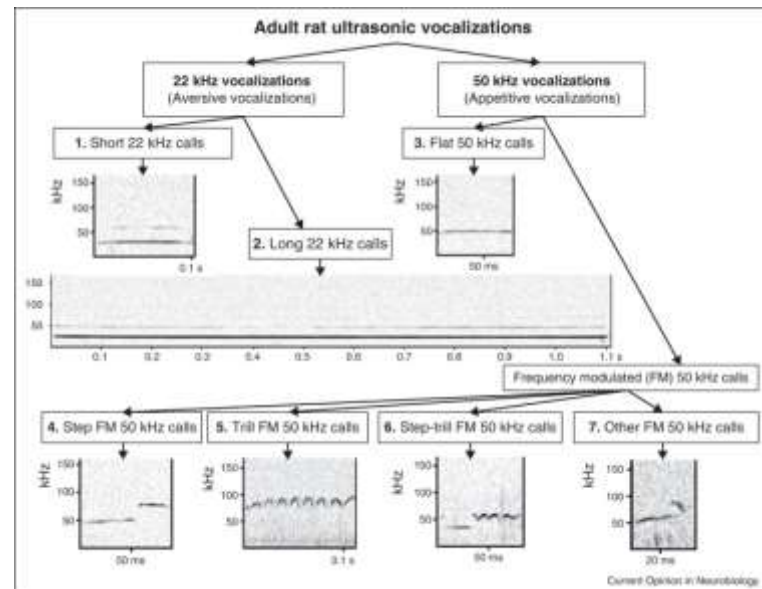


Rats express emotions through ultrasonic vocalizations (USVs)

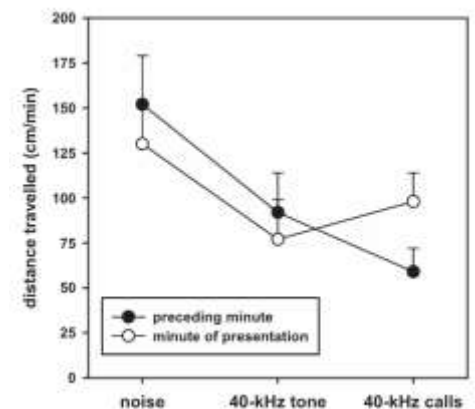
Call Subtype	Mating (Chases)	Play (DC)	Aggression (DC)
22-kHz	-.30*	-.12	-.31*
Flat 50-kHz	-.22	-.14	+.13
FM 50-kHz	+.63**	+.59**	+.35*
Call Subtype	Mating (PEI)	Play (Pin Duration)	Aggression (Freezing)
22-kHz	+.53**	+.41*	+.69**
Flat 50-kHz	-.19	+.35	-.70**
FM 50-kHz	-.57**	-.68**	-.69**

Note. Spearman's correlations were used for all comparisons involving 22-kHz calls and PEI during mating, and Pearson's correlations were used for all other comparisons. USVs = ultrasonic vocalizations; DC = dorsal contacts; FM = frequency modulated; PEI = postejaculatory interval.
* $p < .05$. ** $p < .005$.

Burgdorf J, et al., *J Comp Psychol.*, 2008.

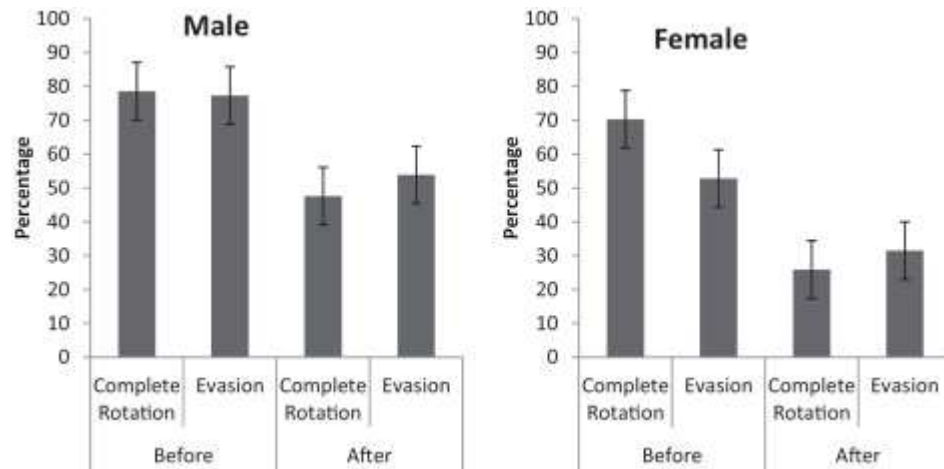


Brudzynski SM., *Curr Opin Neurobiol.* 2013.

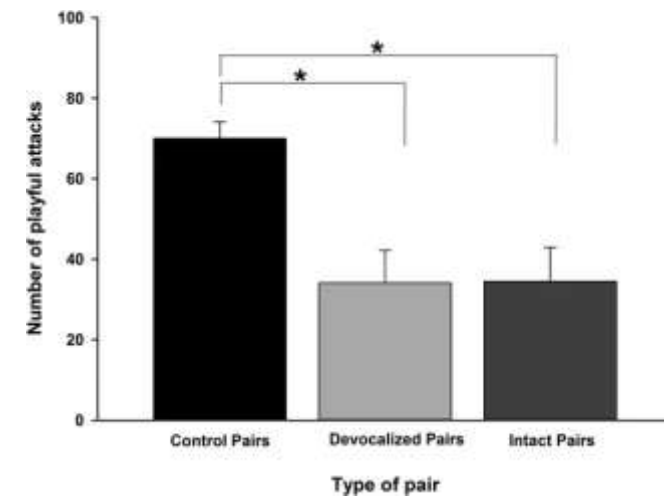


Wöhr, M., & Schwarting, R. K. W., *Behavioral Neuroscience*, 2008.

50-kHz USVs mean “I want to play with you”

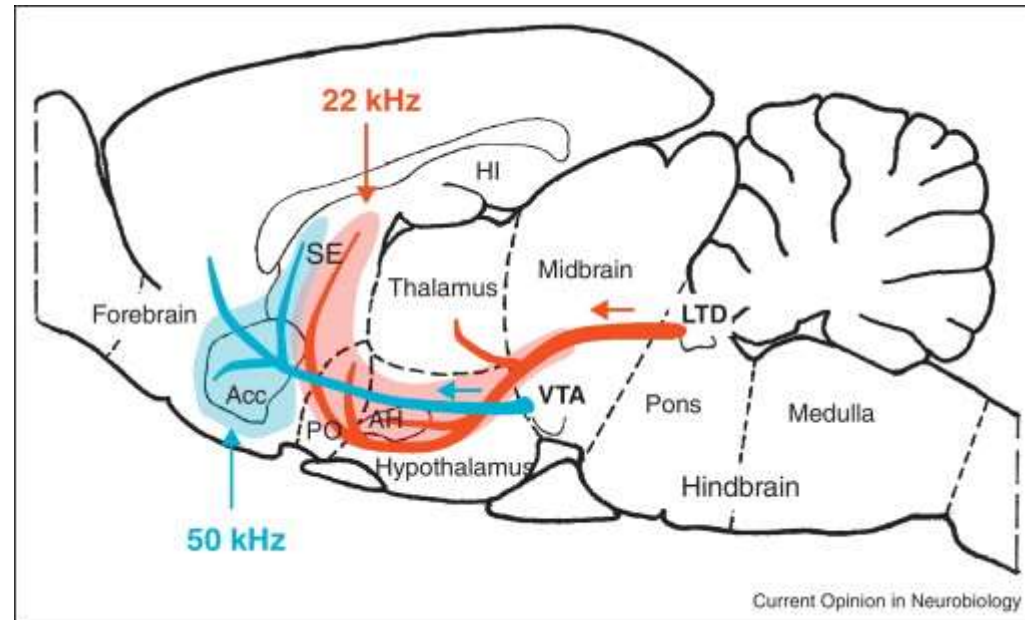


Kisko TM, Euston DR, Pellis SM., *Behav Processes*. 2015



Kisko TM., et al., *Curr Top Behav Neurosci.*, 2017

The emotional valence affects behavior



Brudzynski SM., *Curr Opin Neurobiol.* 2013.

Take home messages

- Play is instinctive in animals.
- Play in childhood promotes healthy development and shapes adult behavior.
- Play behavior is modulated by age, gender, and emotion.

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