Neurorobotics

Module 2: Neurorobot Design Principles

Lecture 5: Design Principle 3 – Behavioral Tradeoffs

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Prologue

Many behavioral tradeoffs made by cognitive agents are regulated by chemicals: Neuromodulators & hormones

Behavioral Tradeoff	Neural Chemical	References
Reward vs. Punishment	Dopamine, Serotonin	(Boureau and Dayan, 2011; Cox and Krichmar, 2009)
Invigorated vs. Withdrawn **Risky vs. Conservative**	Dopamine, Serotonin	(Boureau and Dayan, 2011; Krichmar, 2013)
Expected Uncertainty vs. Unexpected Uncertainty	Acetylcholine, Noradrenaline	(Avery et al., 2012; Bouret and Sara, 2005; Yu and Dayan, 2005)
Explore vs. Exploit	All neuromodulators	(Aston-Jones and Cohen, 2005; Hasselmo and McGaughy, 2004; Krichmar, 2008)
Feed vs. Fight **Forage vs. Nesting**	Orexin	(Aponte et al., 2011; Hahn et al., 1998; Luquet et al., 2005)
Stress vs. Calm	Glucocorticoids	(Rodrigues et al., 2009; Sapolsky, 1996, 2015)
Social vs. Solitary	Oxytocin, Serotonin	(Canamero et al., 2006; Dolen et al., 2013; Rilling and Young, 2014; Tops et al., 2009)

TransAIR Workshop on Cognitive Architectures for Robot Agents

https://transair-bridge.org/workshop-2021/

Neurorobotic Design Principles III – Behavioral Tradeoffs Since Life is Full of Compromises

- The world is full of contradictions and variation that require us to make choices.
- Our changing needs in a dynamic environment leads to tradeoffs we need to assess.
- Implementing behavioral tradeoffs in robots can make them more interesting and relatable.
- Conflict makes for a good story!

Video

https://youtu.be/rb2OQHI7ghW8

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Reward vs. Punishment

Dopamine

Synchronized transient increases in firing rate, i.e. spontaneous bursts, followed by pauses

Phasic activity of dopamine neurons: reward prediction error

Tonic activity of dopamine neurons: average reward rate

Regular firing patterns

Seratonin

Phasic activity of seratonin neurons: punishment prediction error

Tonic activity of seratonin neurons: average punishment rate

Reward vs. Punishment

"Recorded DA neurons fall into one of three categories (Grace and Bunney, 1983; Goto et al, 2007):
(1) inactive neurons;

(2) tonically firing neurons, displaying slow, single-spike firing; and

(3) burst-firing neurons, exhibiting phasic firing driven by afferent input.

Tonic activity reflects general states of arousal or motivation,
whereas phasic activity may be related to the detection and nature of punctate salient events."

(Boureau and Dayan, 2011)

Invigorated vs. Withdrawn

Dopamine

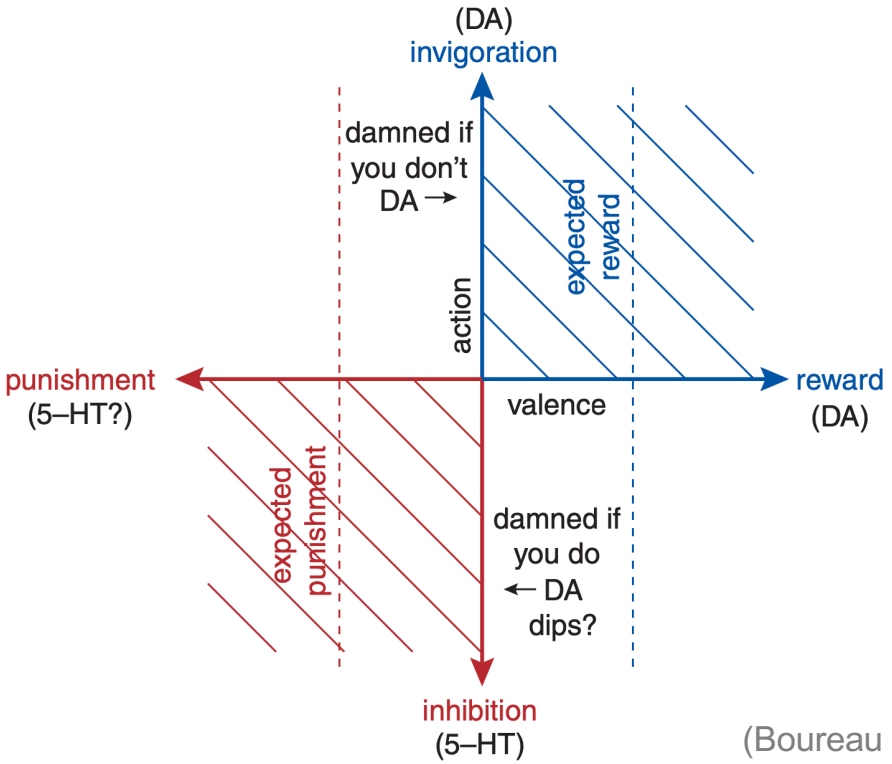
Invigorated novelty seeking behavior

Seratonin

Risk-averse behavior

Opponency

Dopaminergic and seratonergic systems act in opposition for goal directed action



(Boureau and Dayan, 2011)

Expected Uncertainty vs. Unexpected Uncertainty

- Sometimes, uncertainty is expected, & we focus our attention on the task
- Sometimes, uncertainty is unexpected, & we need to divert our attention
- Neuromodulators influence this tradeoff of how to apply attention

Expected Uncertainty vs. Unexpected Uncertainty

Acetylcholine

Cholinergic neuromodulation may track expected uncertainty

The known unreliability in the environment

Noradrenaline

Norandrenergic neuromodulation may track unexpected uncertainty

Observations that violate expectations

Exploration vs. Exploitation

Exploit opportunities that have paid off in the past

- Phasic neuromodulator activity
- Decisive behaviour & exploits the best potential outcome at that moment

Explore new options

- Tonic neuromodulator activity
- Somewhat arbitrary behavior

Foraging vs. Defending

Hormones regulate a number of bodily functions

- Body temperature
- Thirst
- Hunger
- Sleep

Hormones can be triggered by environmental events

- Broadly change neural activity

Foraging vs. Defending

A hormone called orexin regulates hunger levels

- This can lead to a behavioral tradeoff in which animals foraging for food are less willing to defend a territory

Stress vs. Calm

The fight or flight response is mediated by stress hormones: glucocorticoids

- Increases blood flow
- Increases awareness

Chronic stress due to elevated glucocorticoids can cause damage to the hippocampus and memory

Social vs. Solitary

Hormones can regulate a tradeoff between social bonding and independence

- Estrogen
- Progesterone
- Oxytocin
- Prolactin

"Cuddle / hug hormone"
Oxytocin is released when people or pets snuggle up or bond socially.

can influence a number of neural systems to ensure maternal nurturing, bonding, and protection of young

Reading

Hwu, T. and Krichmar, J. (2022). Neurorobotics: Connecting the Brain, Body and Environment, MIT Press.

Chapter 6, Sections 7.1 - 7.8, pp. 126 - 136

References

Boureau, YL., Dayan, P. Opponency Revisited: Competition and Cooperation Between Dopamine and Serotonin. Neuropsychopharmacol 36, 74–97 (2011). https://doi.org/10.1038/npp.2010.151