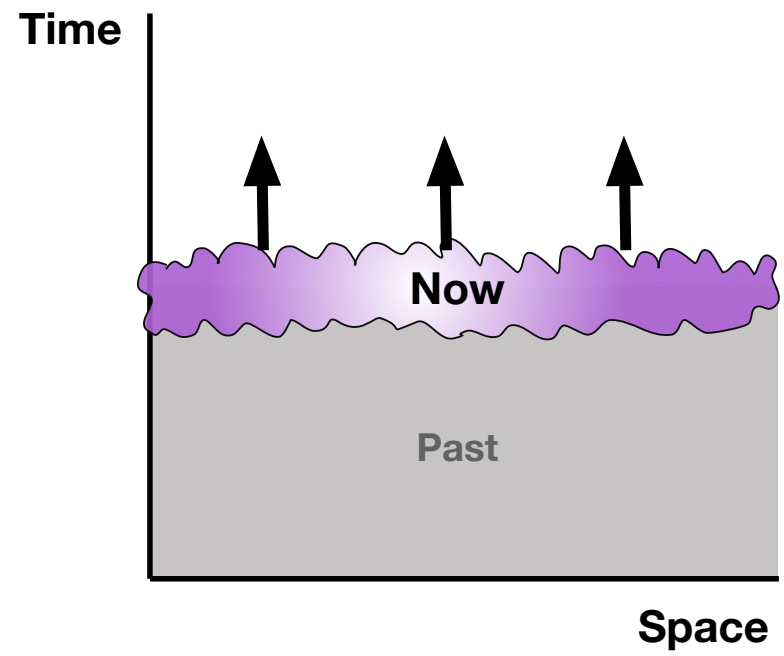
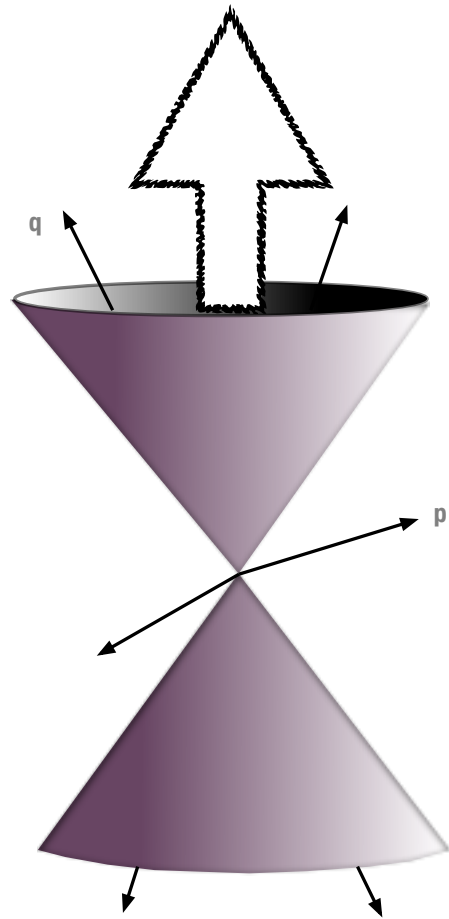


**Arrow of Time**



**Passage of Time**

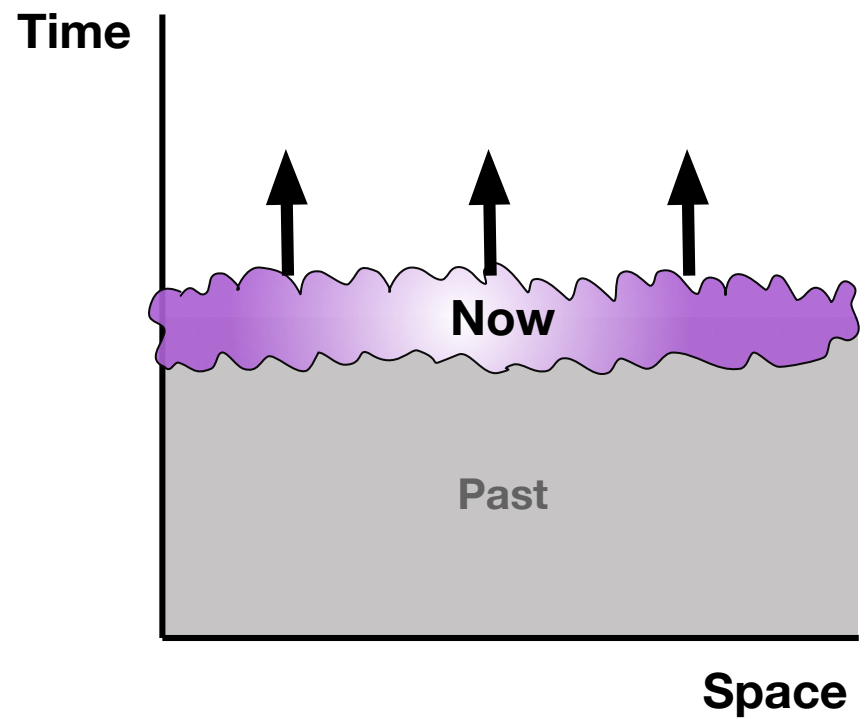


## Arrow of Time

- Which arrows?
- Lawlike or factlike? Connection?
- Universal or Reichenbachian branches?
- Cause of the thermodynamic arrow?
- Cause of quantum arrow?
- Special initial conditions: what are they? do they have an explanation?
- Can we give the usual thermodynamic story when gravity is “turned on”?
- What is the connection between the physical arrows and the knowledge na causal arrows?
- Etc

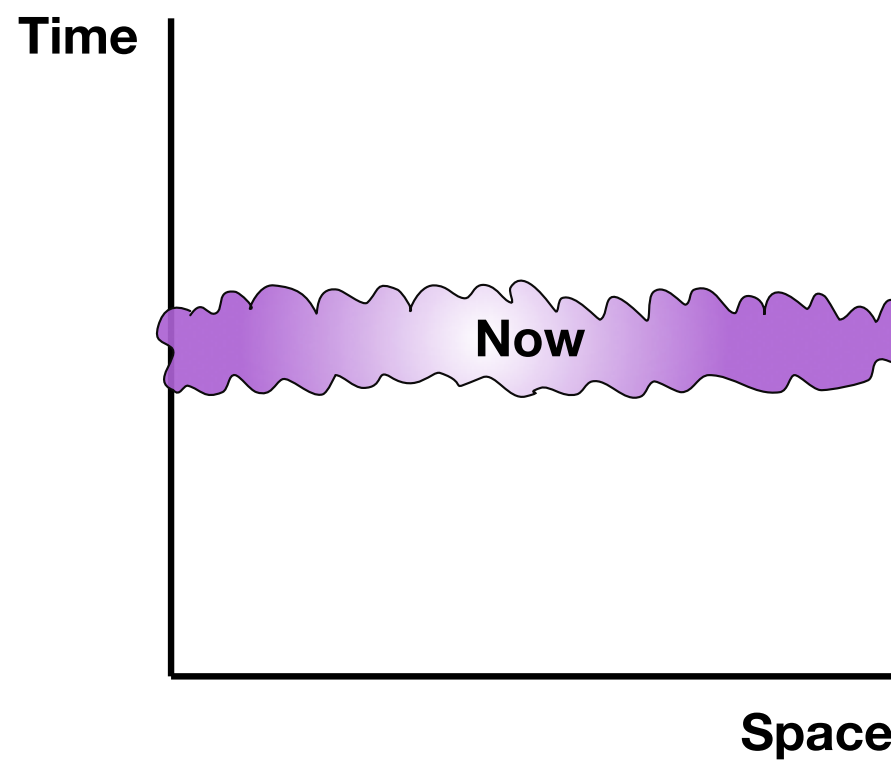
*A-series or tensed time*  
(philosophers)

*Deitic time*  
(cognitive scientists,  
linguists)



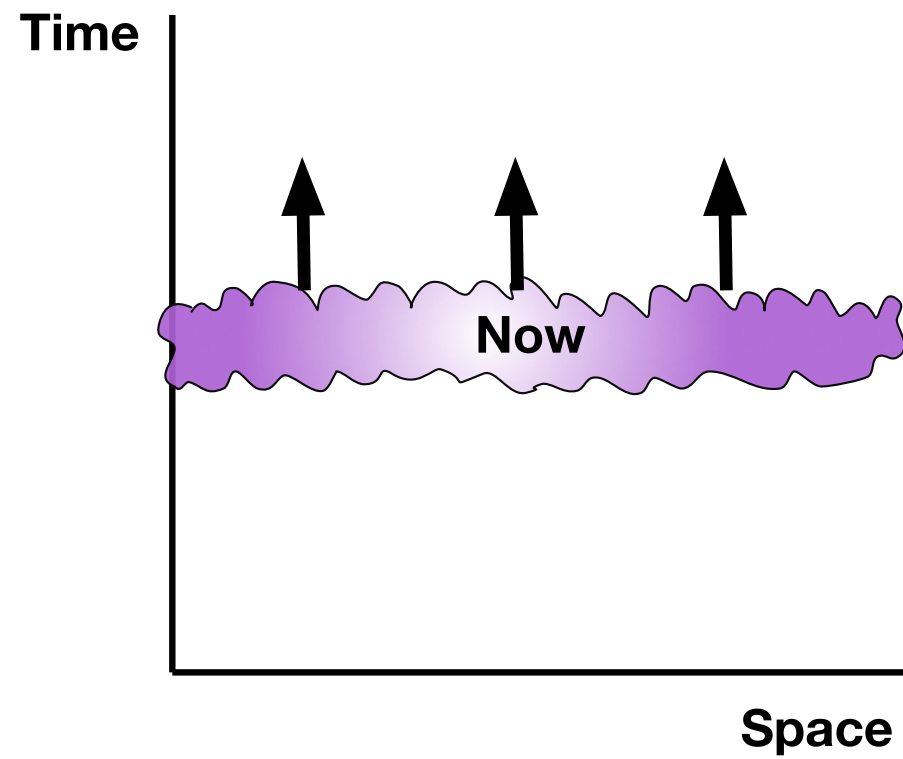
**Passage of Time**

Distinguished Present or  
Now



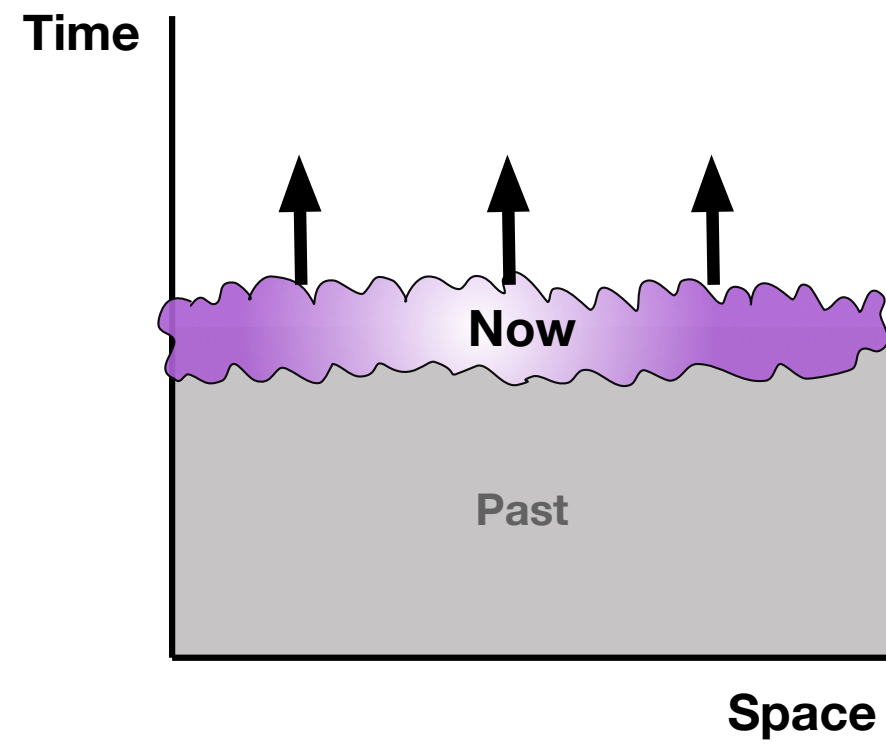
**Passage of Time**

The Now Updates Itself,  
or Flows



**Passage of Time**

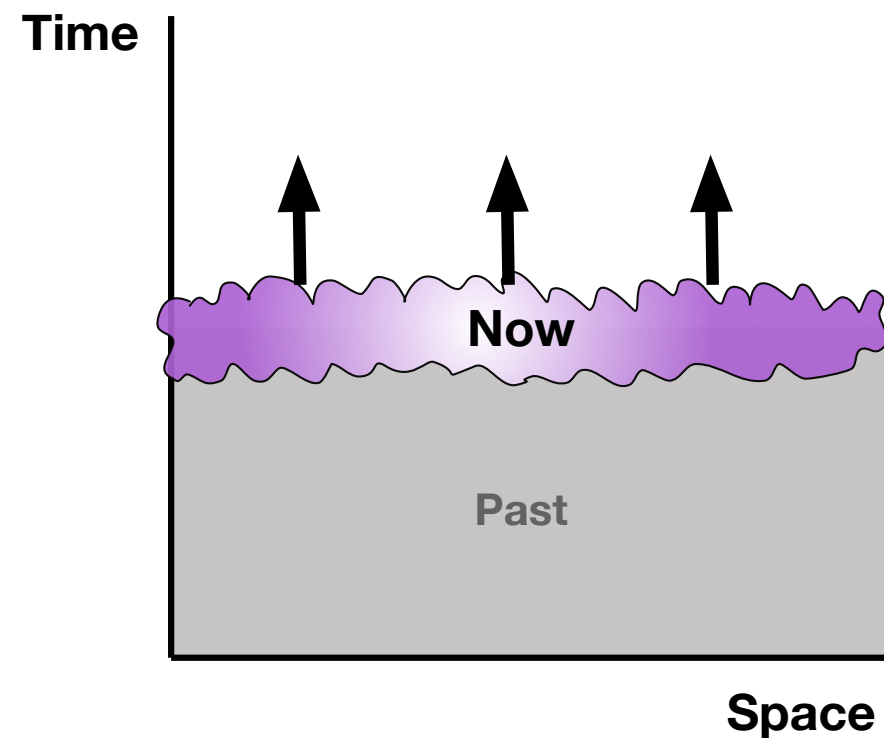
The Past is “Dead”



Passage of Time

## Universal?

Lots of cultural variation when time is represented spatially, e.g., gestures. Ironically (given how this work is sometime reported), this work shows how universal deitic time is. Virtually all languages also represent time as dynamic. Deep feature of language, thought and behavior.



**Passage of Time**

# Big Problem

Physics claims that the time of our lives -- deitic time -- is basically *rubbish*.

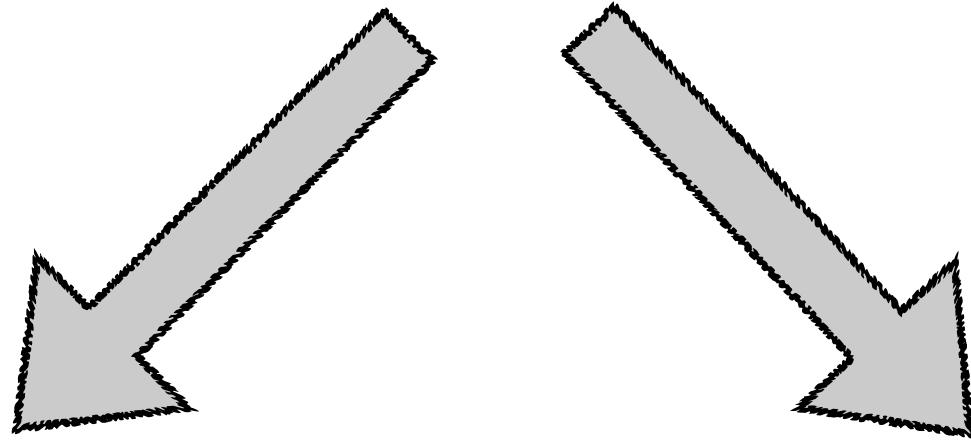


The equations make sense, but they don't satisfy those who ask why we perceive a "now" or why time seems to flow the way it does.

*Science*, July 2005

[T]his coldblooded  
mathematical formulation  
doesn't do justice to the  
experience we all have of  
being in time.

*New York Times*, July 2013



Metaphysics  
New physics

Illusion

# Metaphysics to the Rescue?



Callender 2008,  
2011



We ought to eliminate this flow idea from the real picture [of the world], but before we can eliminate it we ought to understand how it arises. We should understand that there can be a self-consistent set of rules that would give a beast this kind of phoney picture of time.

--Thomas Gold 1967, 182.

In theory, one should be able to create this feeling of nowness in a sufficiently elaborate machine.

--Mr X.

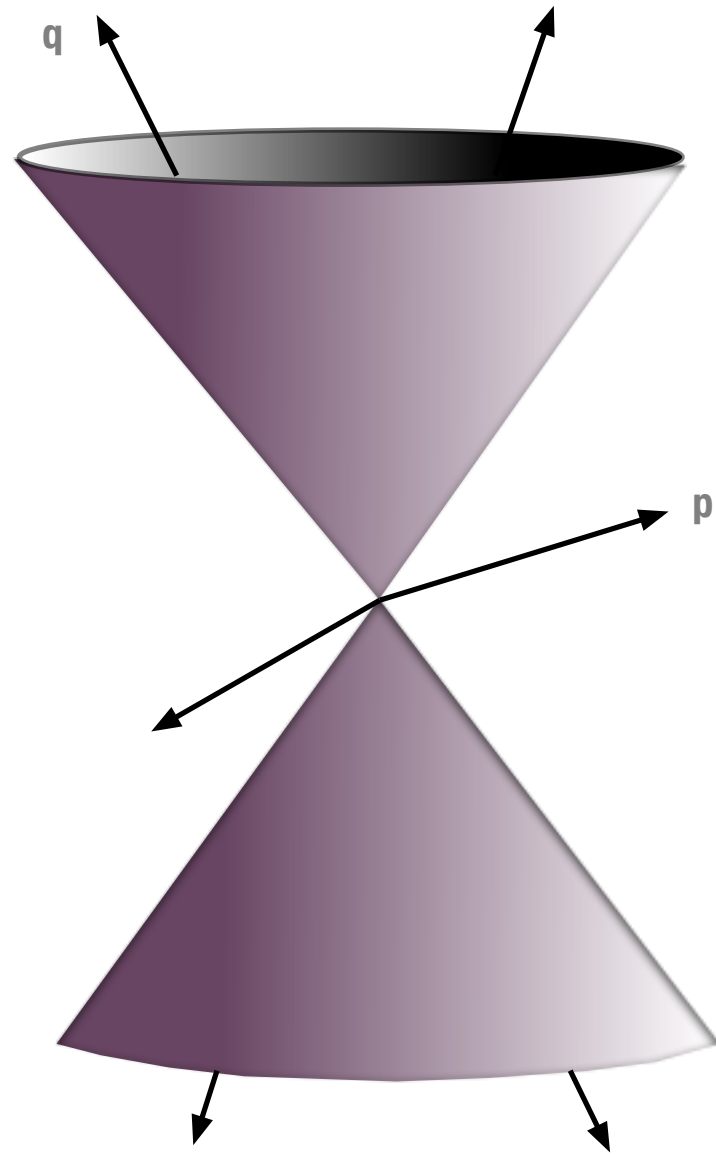
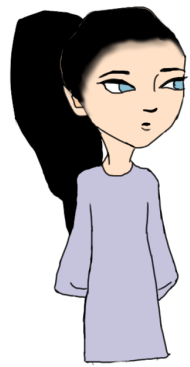
(Gleick, 1982; Feynman vs Grünbaum)

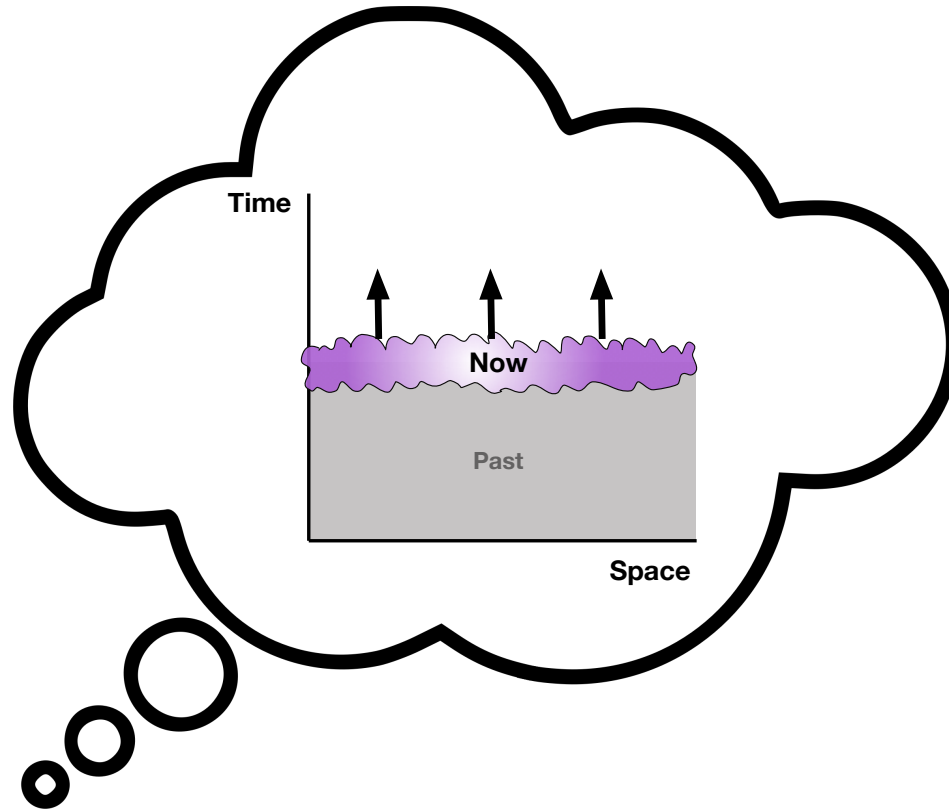
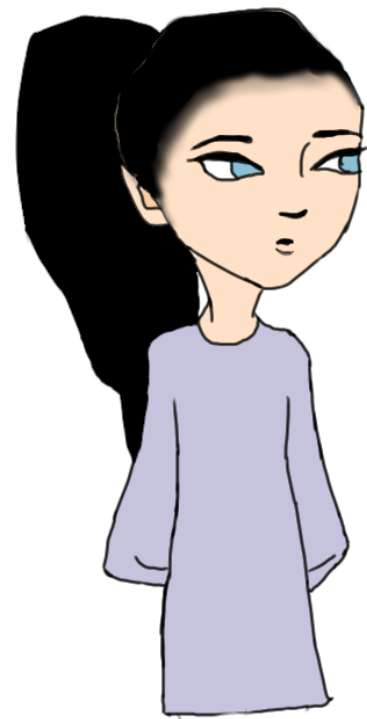


<http://pixabay.com/p-19329/>

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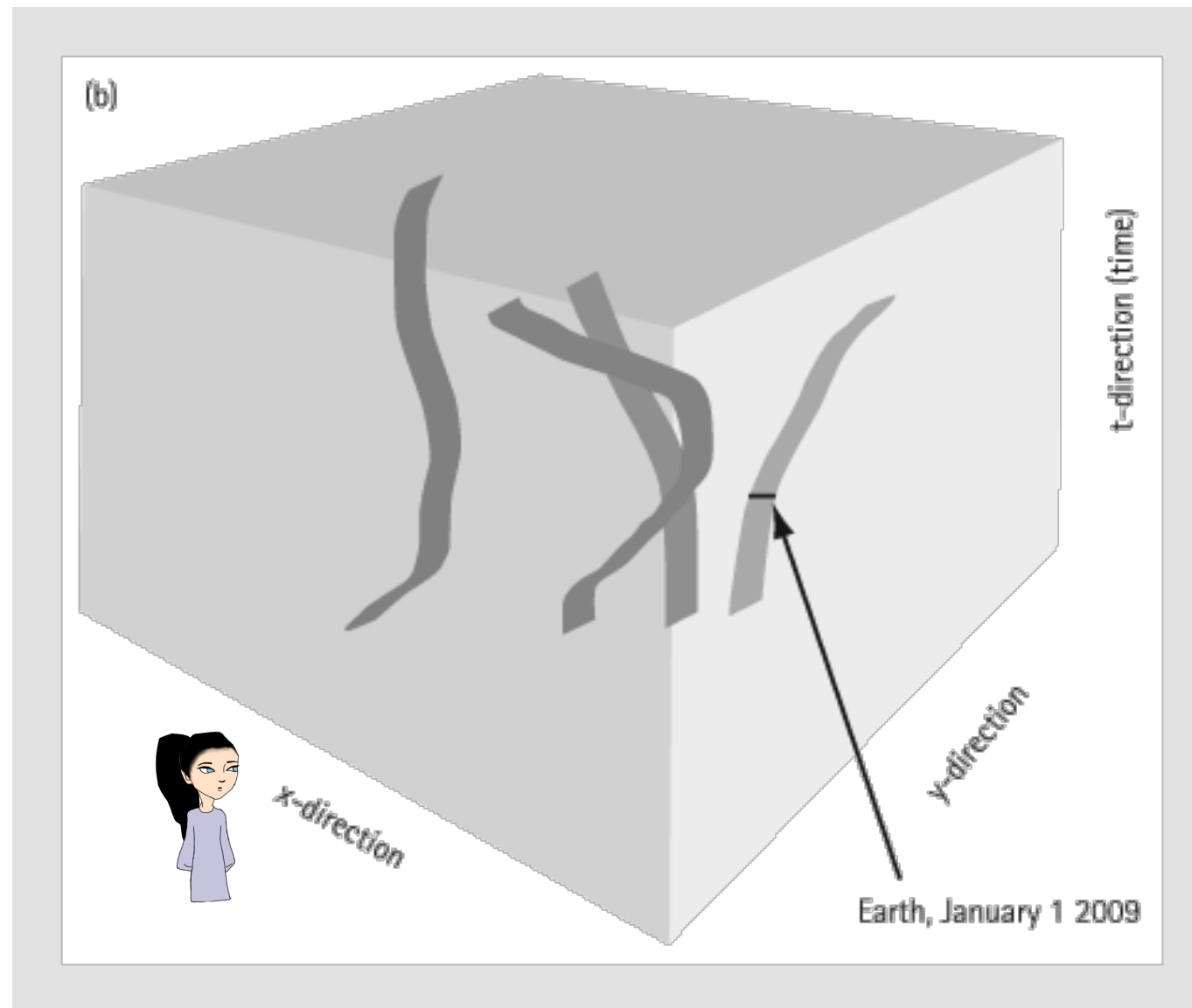
WHY I STOPPED WORRYING AND  
LEARNED TO LOVE THE BLOCK





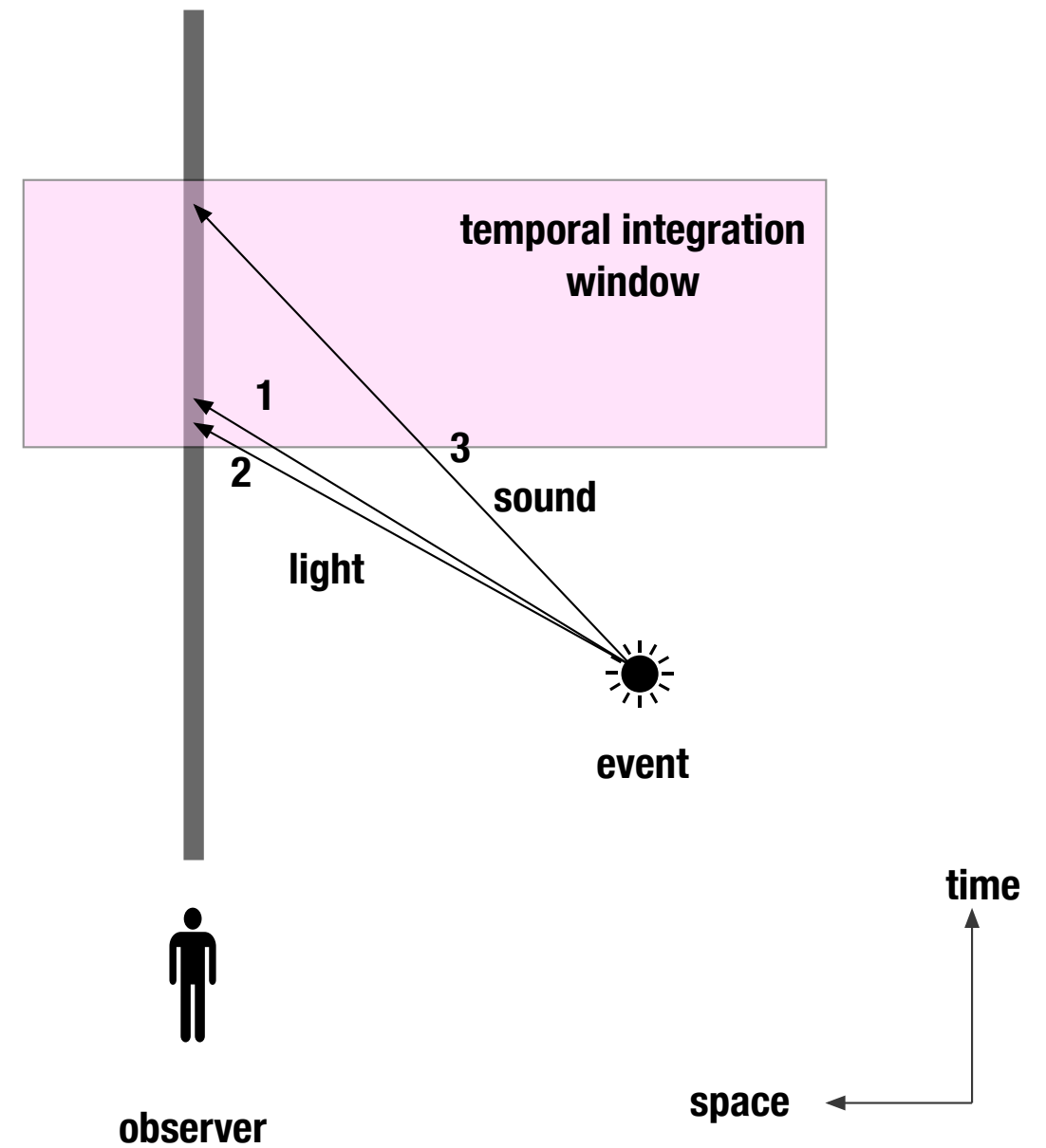


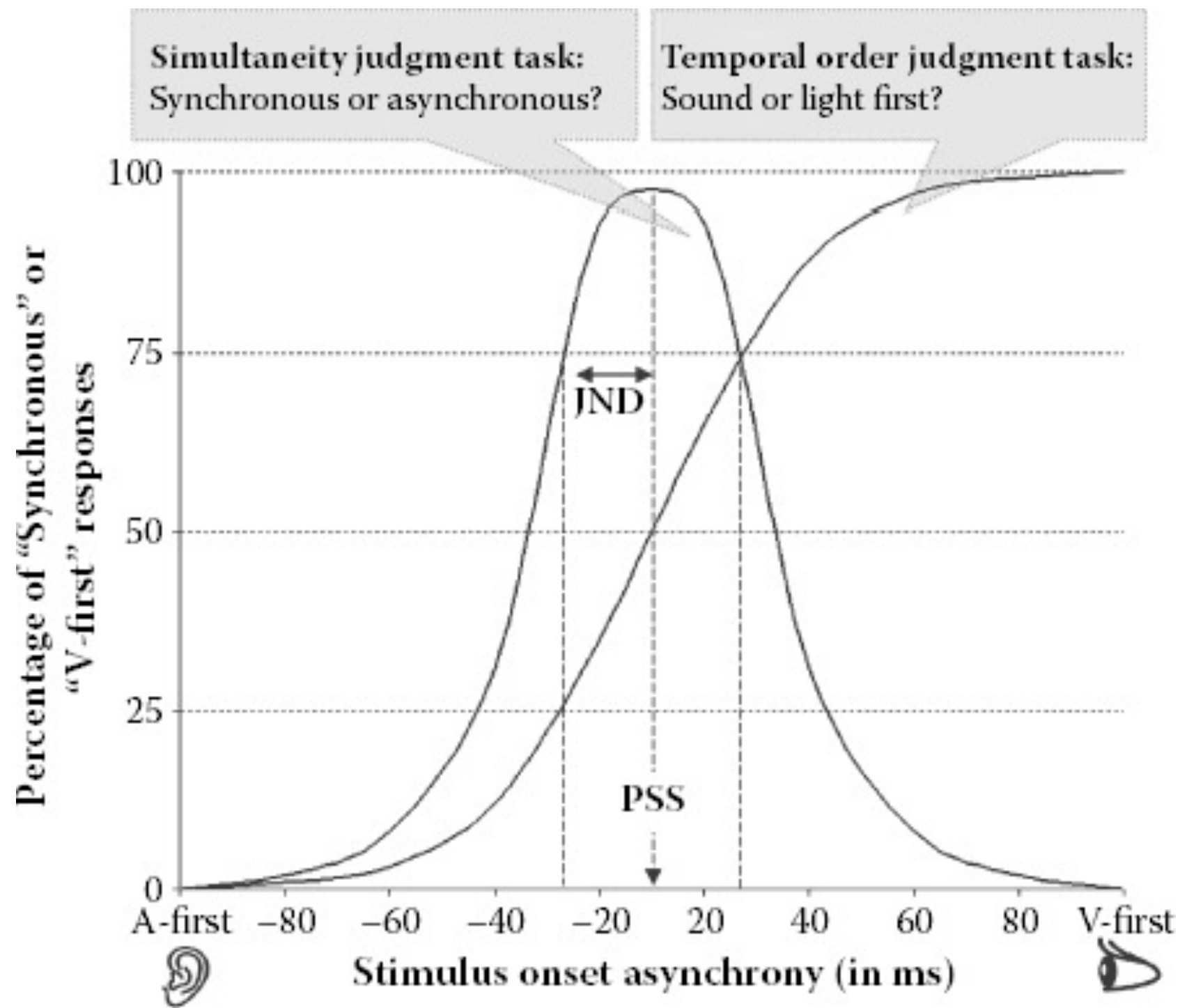
# My Approach

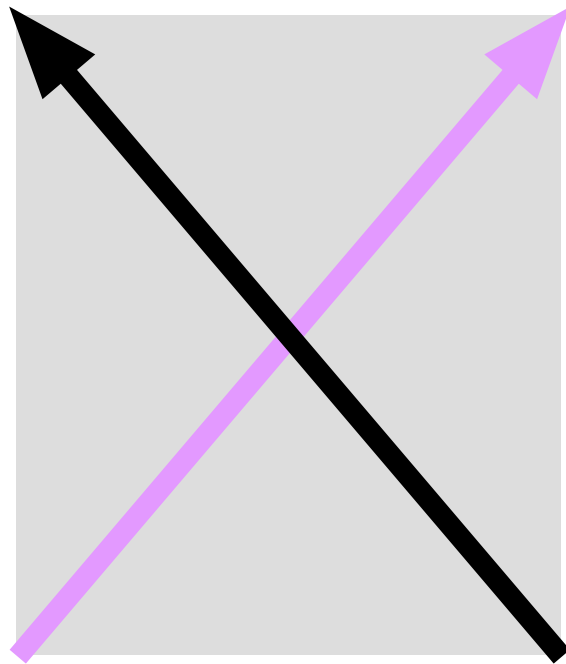


**modeling time as deictic is a natural reaction to challenges faced by organisms like us**

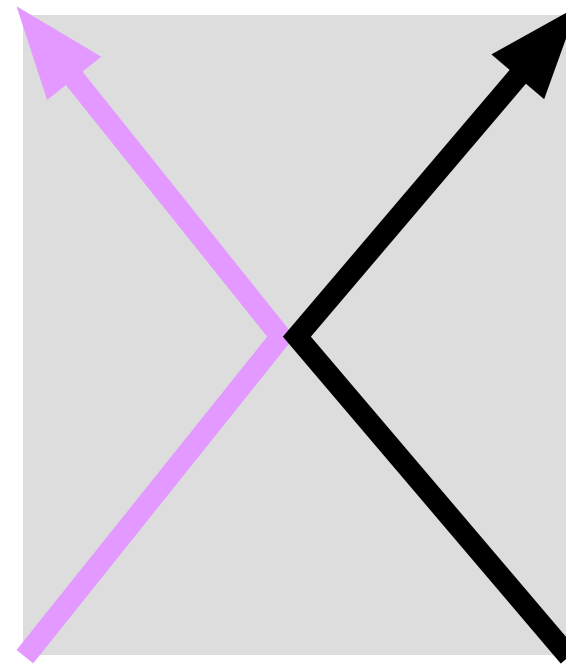
**Challenge:** represent the objective temporal sequence — despite being bombarded by signals at varying speeds and features



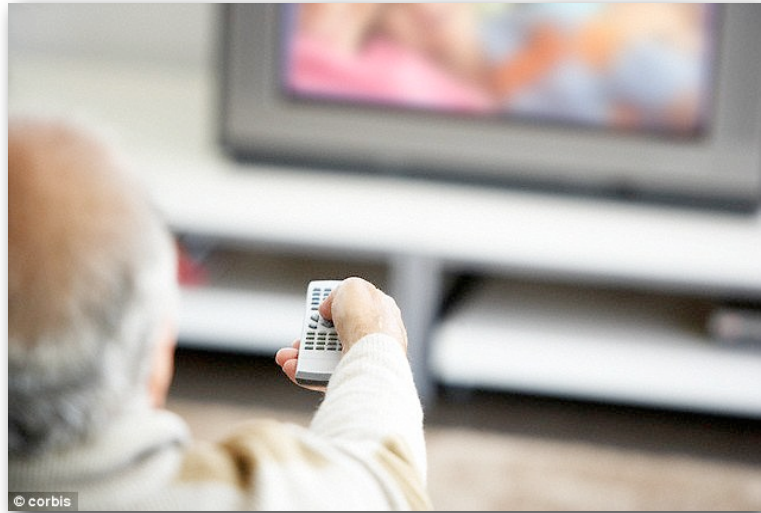




**Stream**



**Bounce**



**Sound leads light**

$PSS_{TOJ} = 210 \text{ msec}$

**Audiovisual Integration**

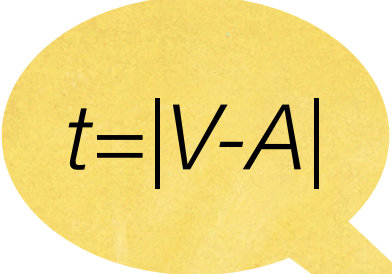
Max = -240 msec

---

**Gain/Cost****Integration ( $I = 1$ )****No integration ( $I = 0$ )**

---

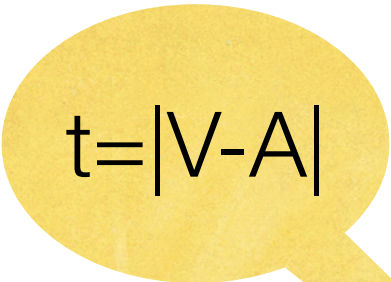
Common source ( $C = 1$ ) $U_{11}$  $U_{10}$ Separate sources ( $C = 2$ ) $U_{21}$  $U_{20}$


$$t = |V - A|$$

### Decision Rule

If  $P(C=1/t)/P(C=2/t) > U_{20} - U_{21} / U_{11} - U_{10}$

then integrate; otherwise, don't.


$$t=|V-A|$$

### Decision Rule

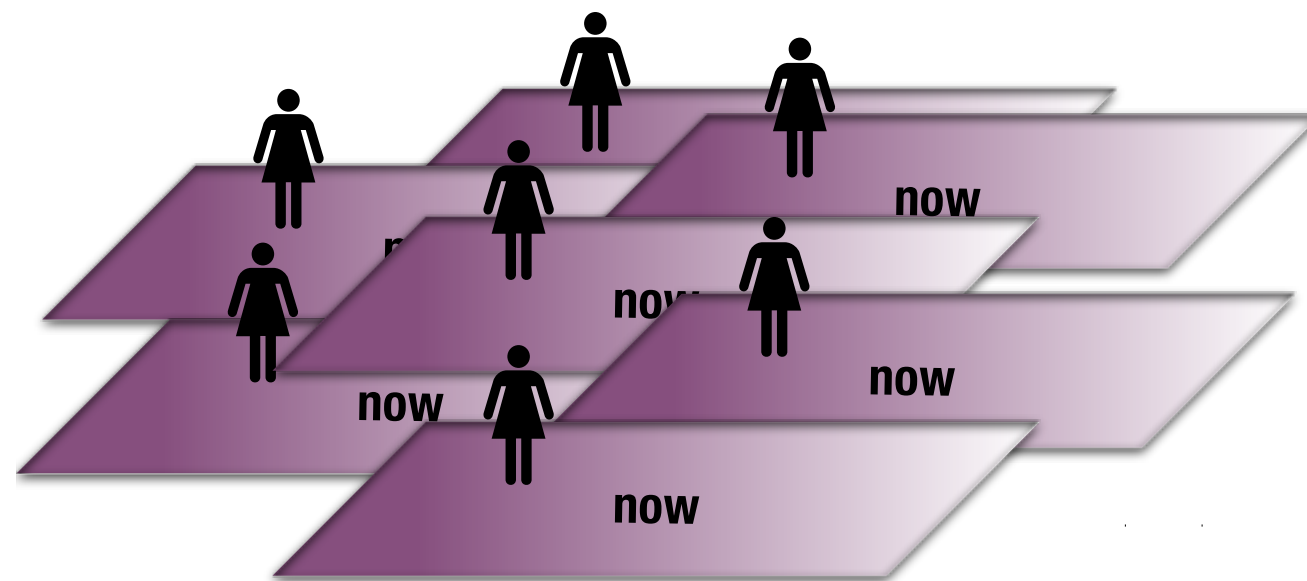
If  $P(C=1/t)/P(C=2/t) > U_{20}-U_{21} / U_{11}-U_{10}$

then integrate; otherwise, don't.

Making a few assumptions, we can infer that:

- increasing the prior probability of a common cause ( $C=1$ ) will make optimum window larger
- keeping red values fixed, an increase in  $U_{11}$  leads to a window increase
- keeping red values fixed, a decrease in  $U_{20}$  leads to narrowing of window

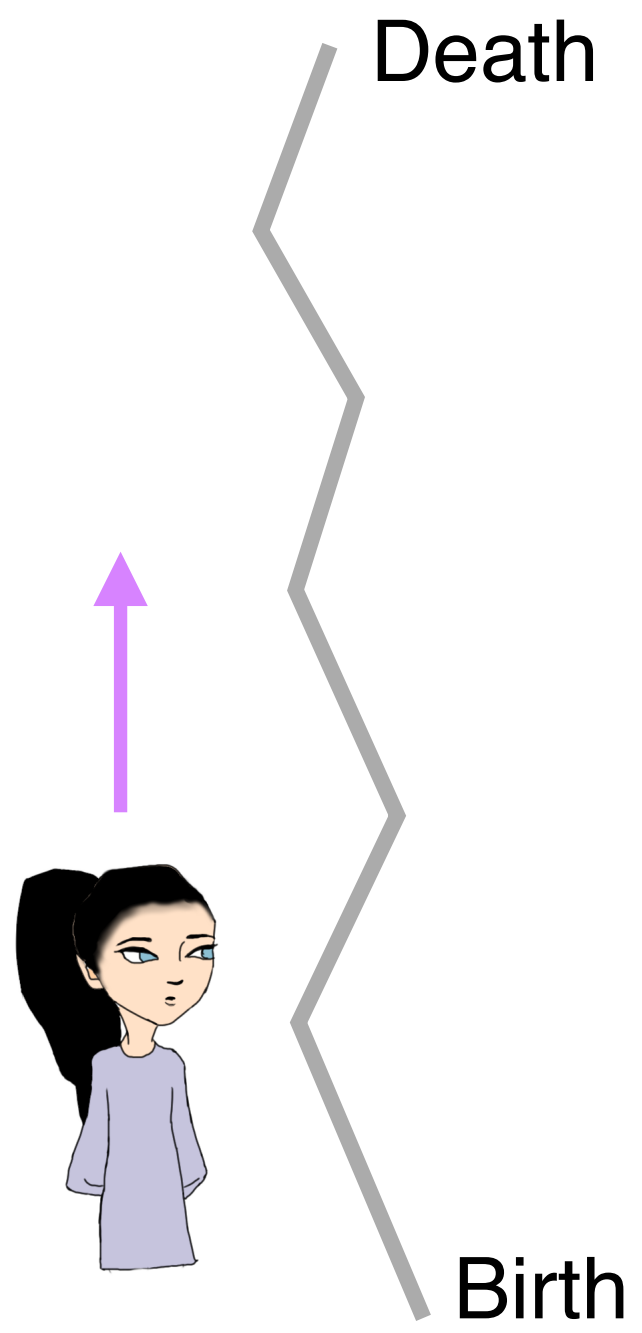


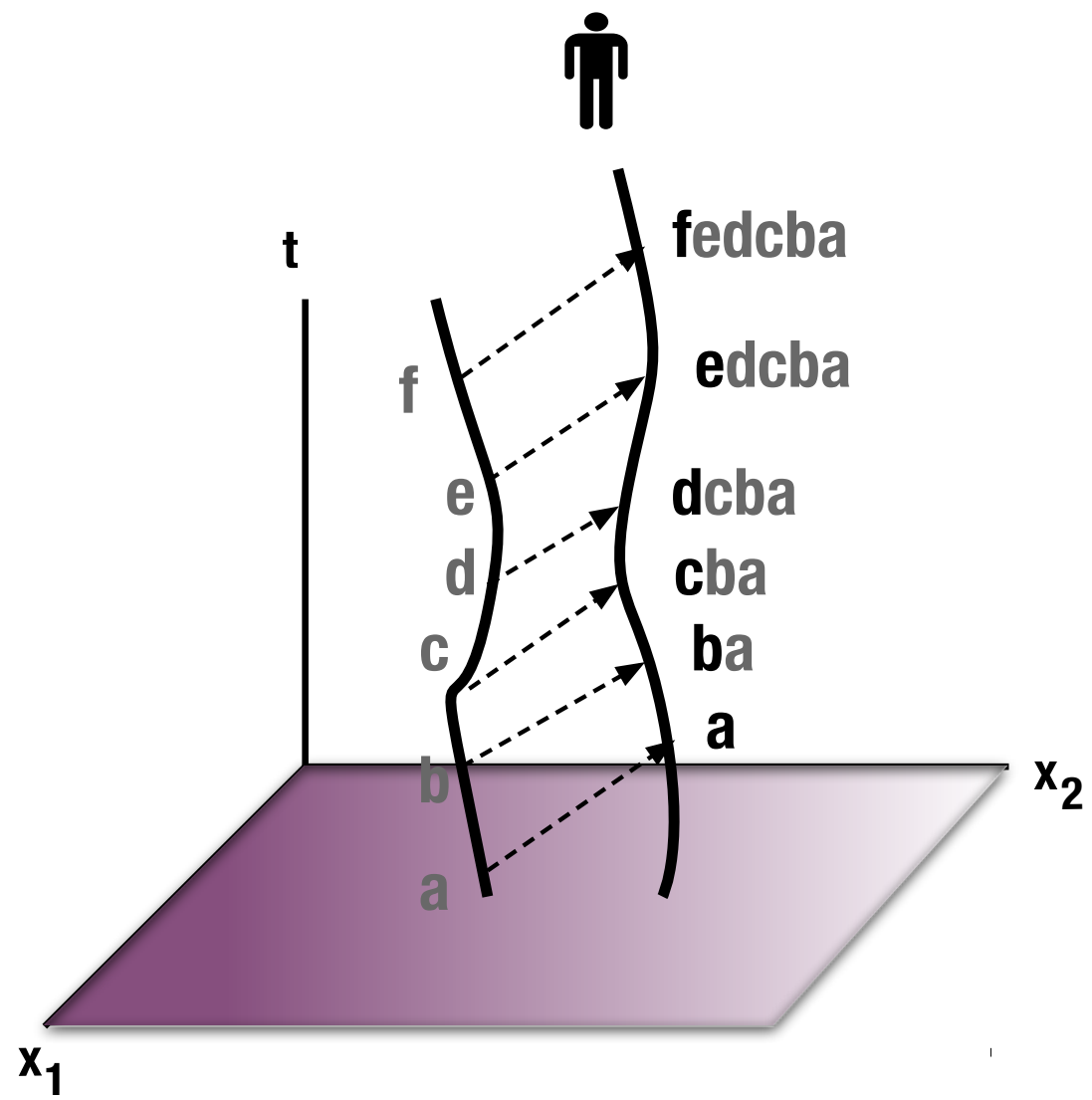


Butterfield 1984, Callender 2008, 2016

**Challenge:** distinguish  
between self and other  
(Dennett)







Mellor, Greene, Dainton, others

**Time presupposes a view of time. It is, therefore, not like a river, not a flowing substance. The fact that the metaphor based on this comparison has persisted from the time of Heraclitus to our own day is explained by our surreptitiously putting into the river a witness of its course.**

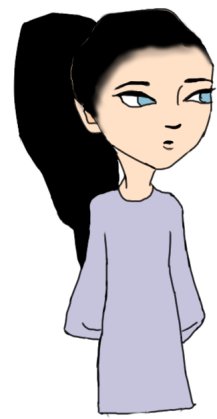
-Merleau-Ponty

**...we think that time "passes," flows past us, but what if it is we who move forward, from past to future, always discovering the new?**

-Ursula K. Le Guin, *The Dispossessed*

**The illusion of time flowing originates in the illusion of an enduring self.**

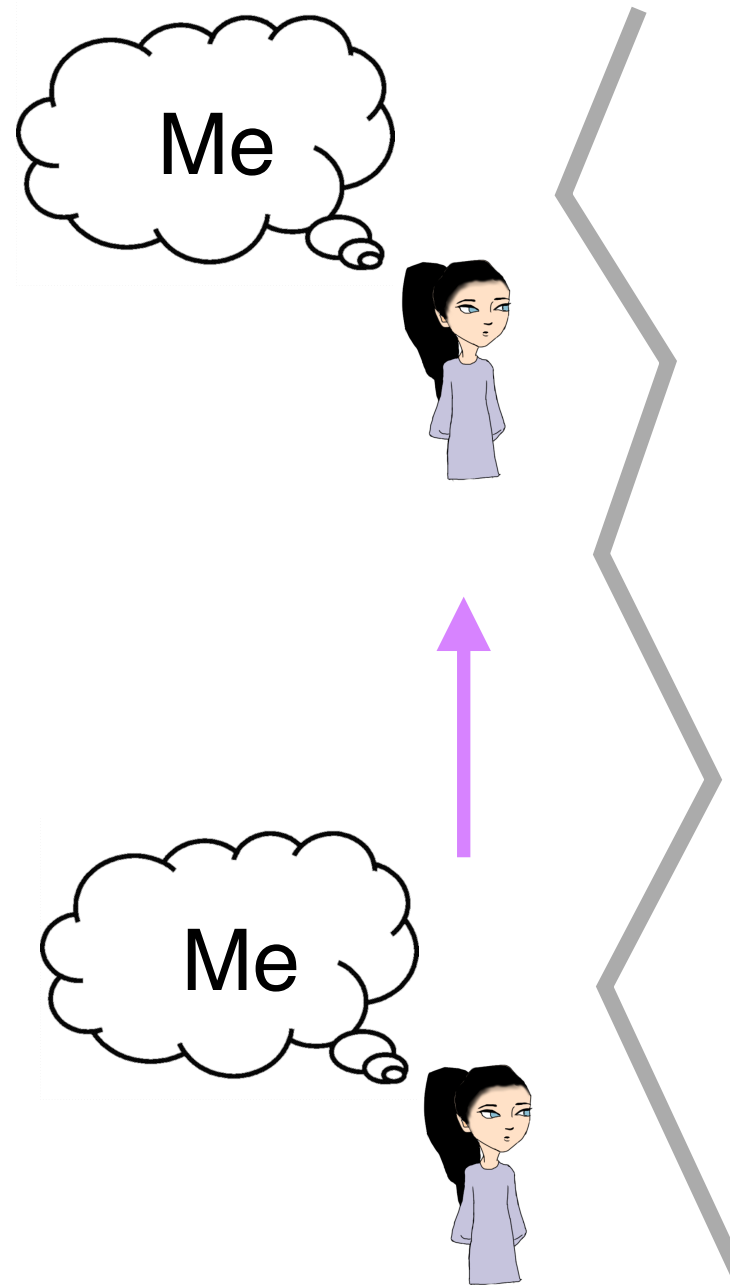
-Buddha(?) via Velleman



I am Iggy

## Narrative Self

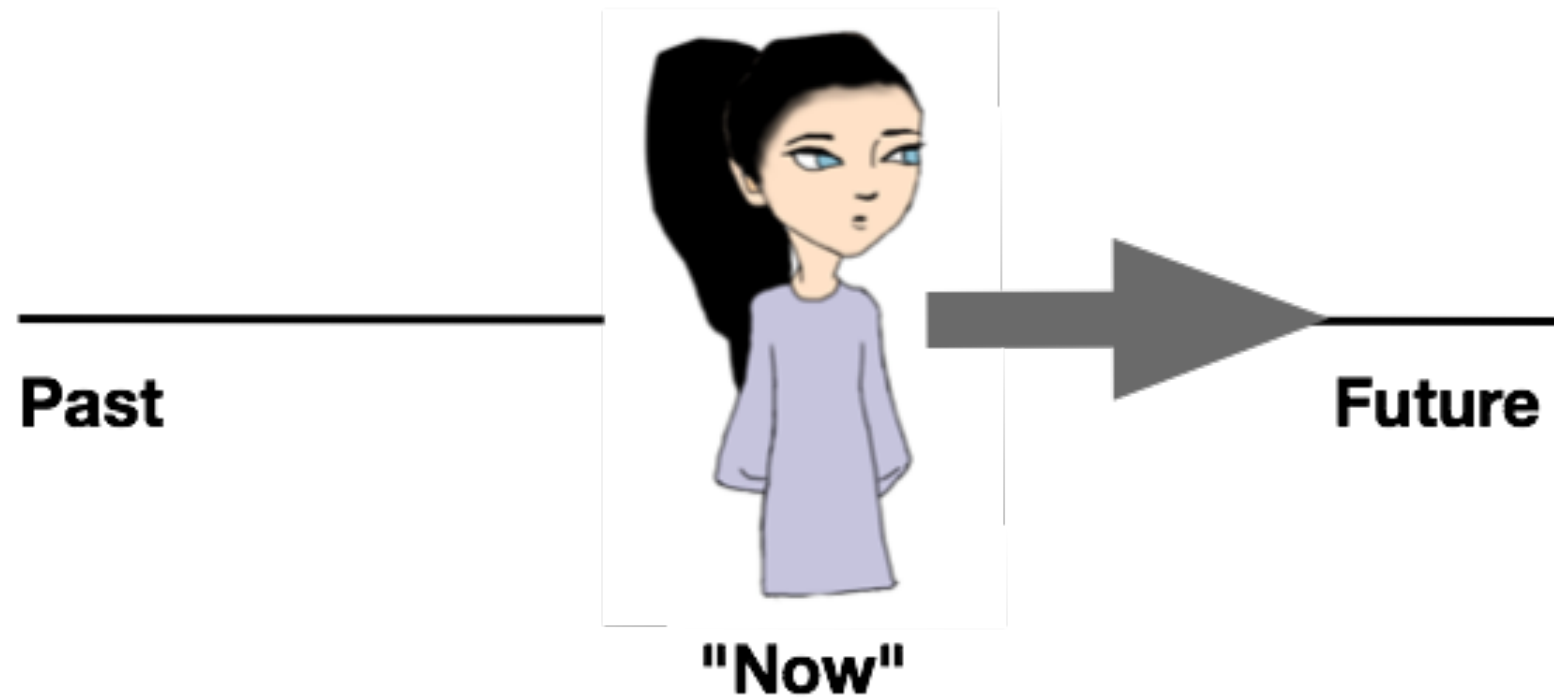
‘our lives have a narrative structure — roughly speaking, they comprise an unfolding, structured sequence of actions, events, thoughts, and feelings, related from the individual’s point of view.’ (Goldie, 2000, p. 4)



# Can We Make Contact with Science?

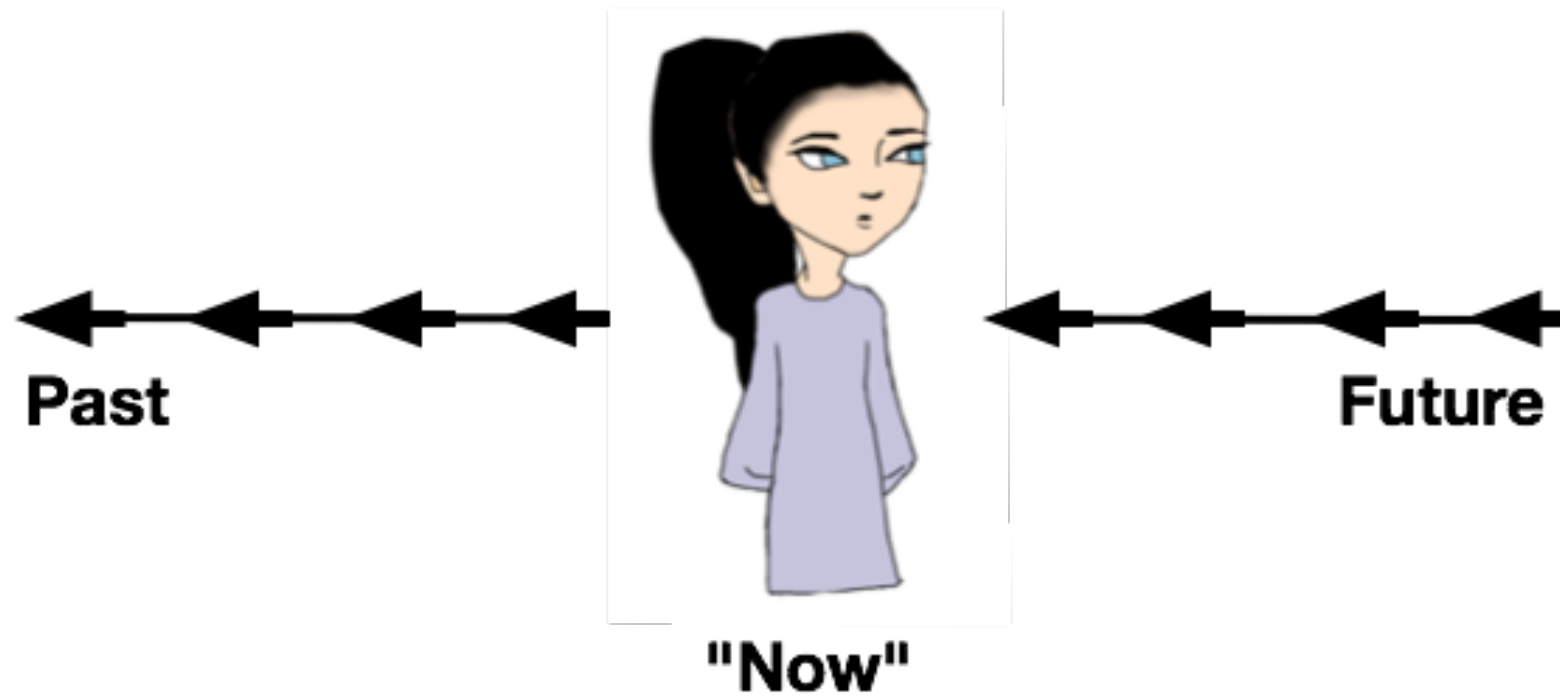
1. Cognitive metaphor theory suggests that once we get an enduring ego we also get the idea that time flows.
2. Developmental psychology suggests that representing deitic time is crucially dependent upon development of self-conception
3. Prediction: there will be correlations amongst performance on diagnostics of (a) self-conception, (b) “auto-biographical” memory, and (c) temporal decentering.





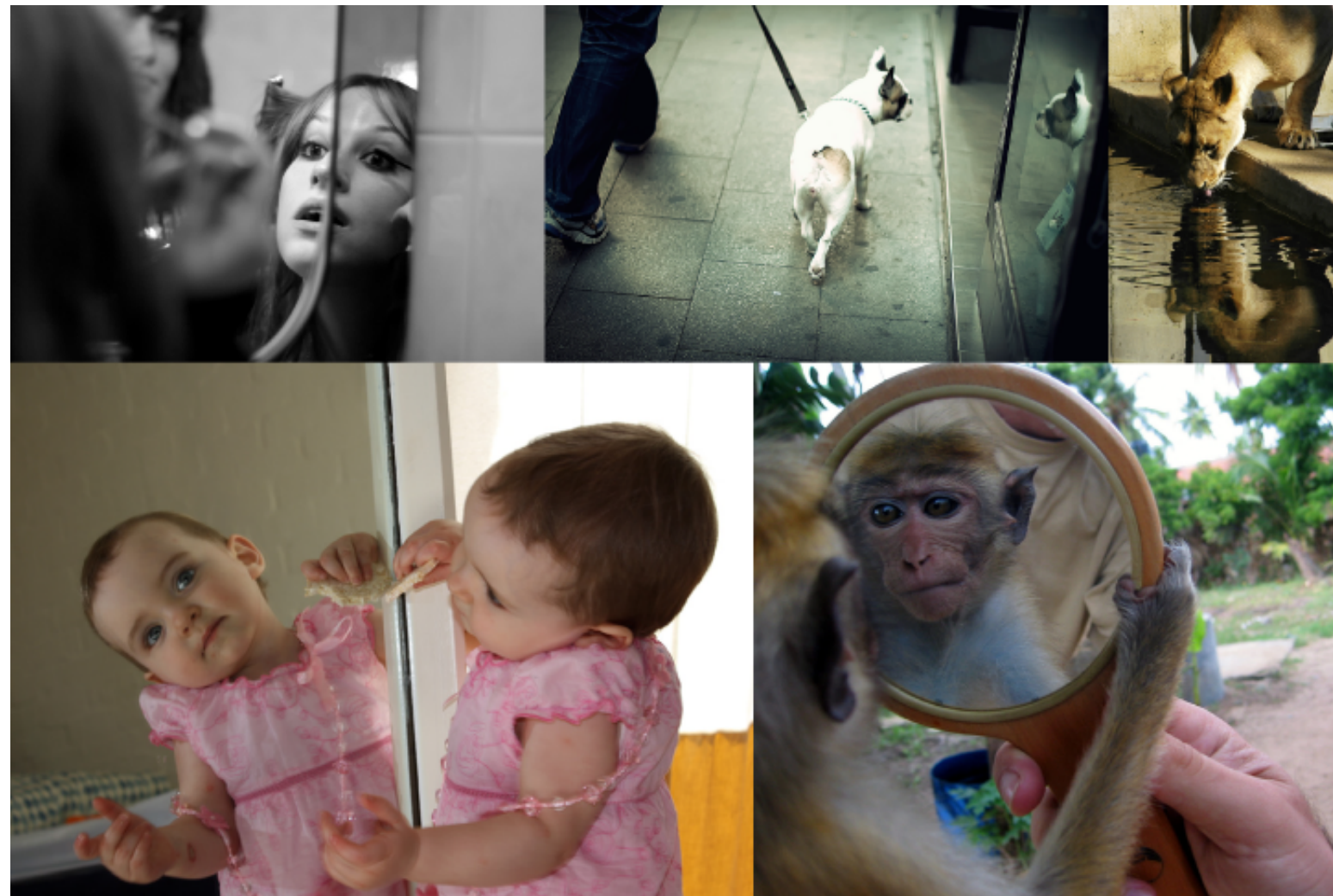
# Ego Moving

McGlone and Harding 1998;  
Gentner and Boroditsky 2000



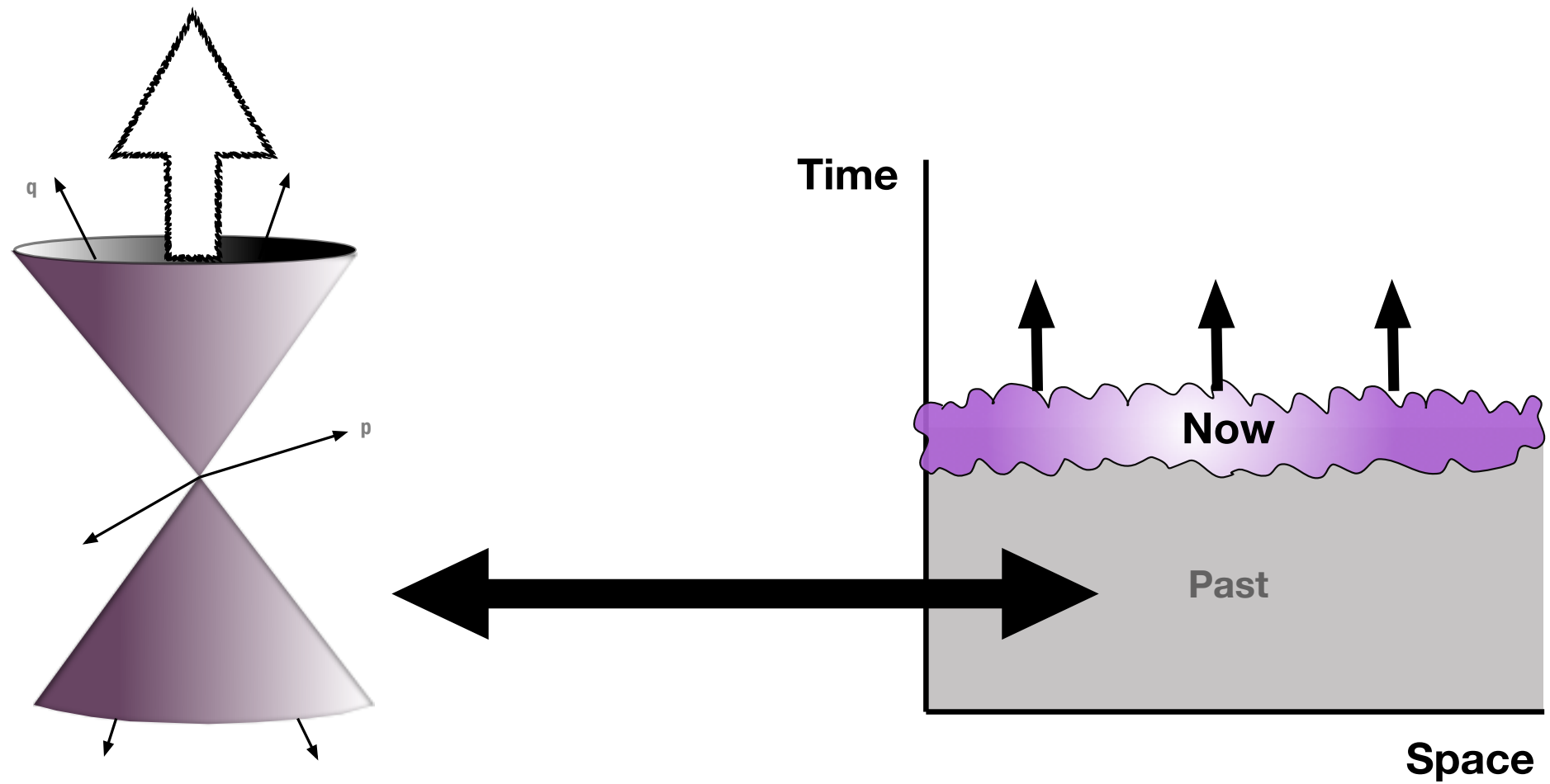
**Time Moving**

Temporal decentering is “associated with a grasp of the fact that there were previous points in time at which one’s temporal perspective on events was quite different but one’s own nonetheless” (McCommack and Hoerl 1999, 174). See Campbell 1994; Neisser, 1991; Povinelli et al., 1996; Povinelli & Simon, 1998

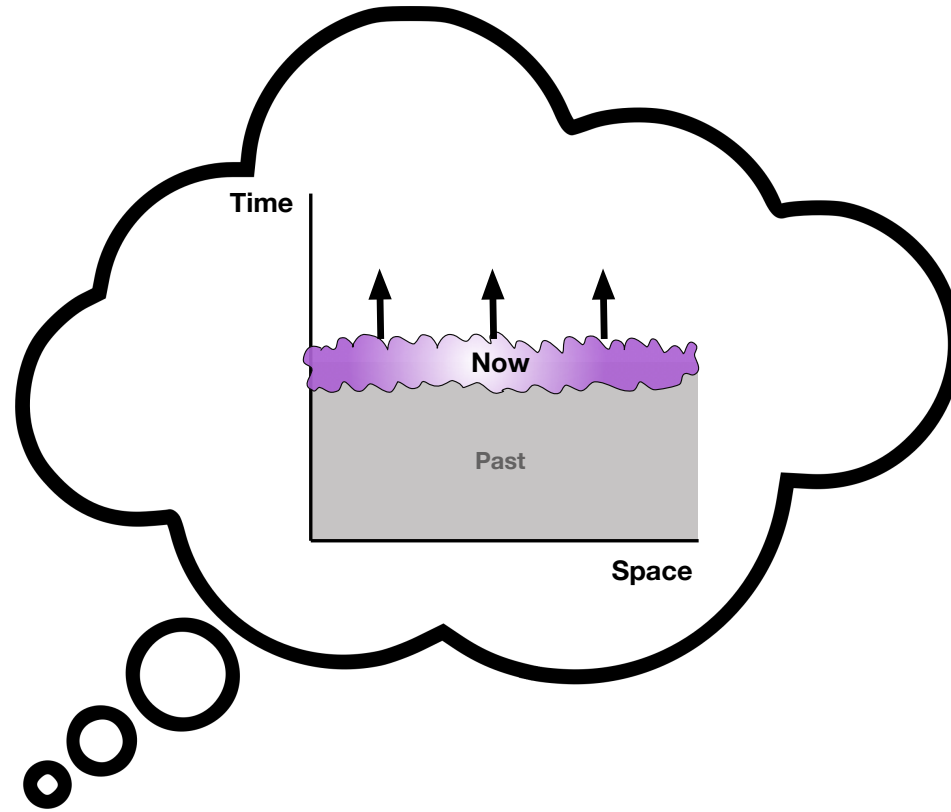
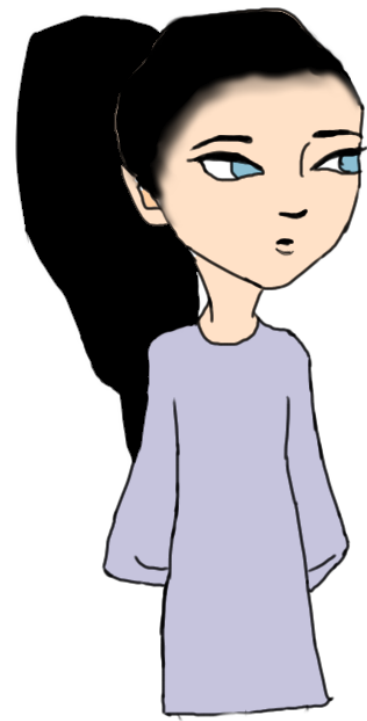


**Challenge:** build cognitive and physiological systems that increase fitness (and hence recognize arrows of time)

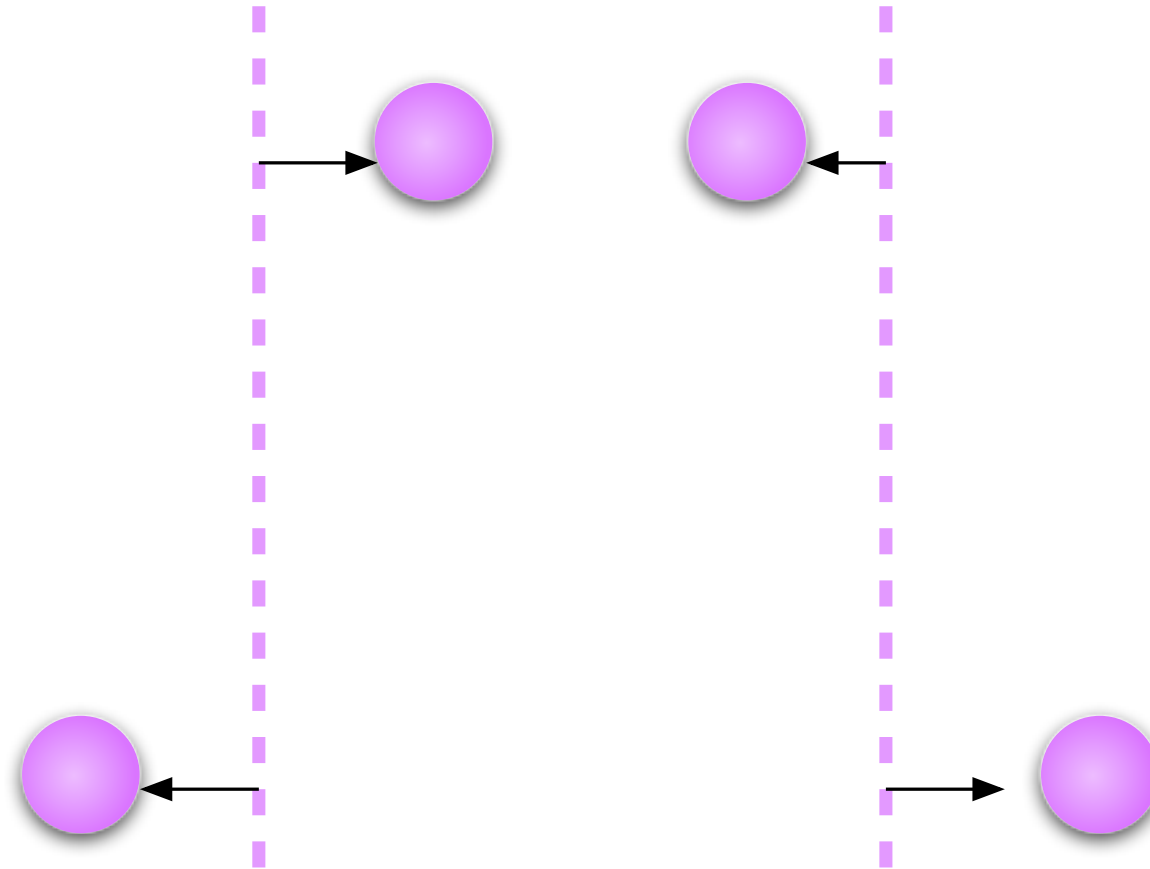




Callender and Suhler 2012  
Ismael, Albert, Price



**Voluntary  
Action**



**Involuntary  
Action**

**Baseline  
action  
awareness**

**Baseline  
effect  
awareness**