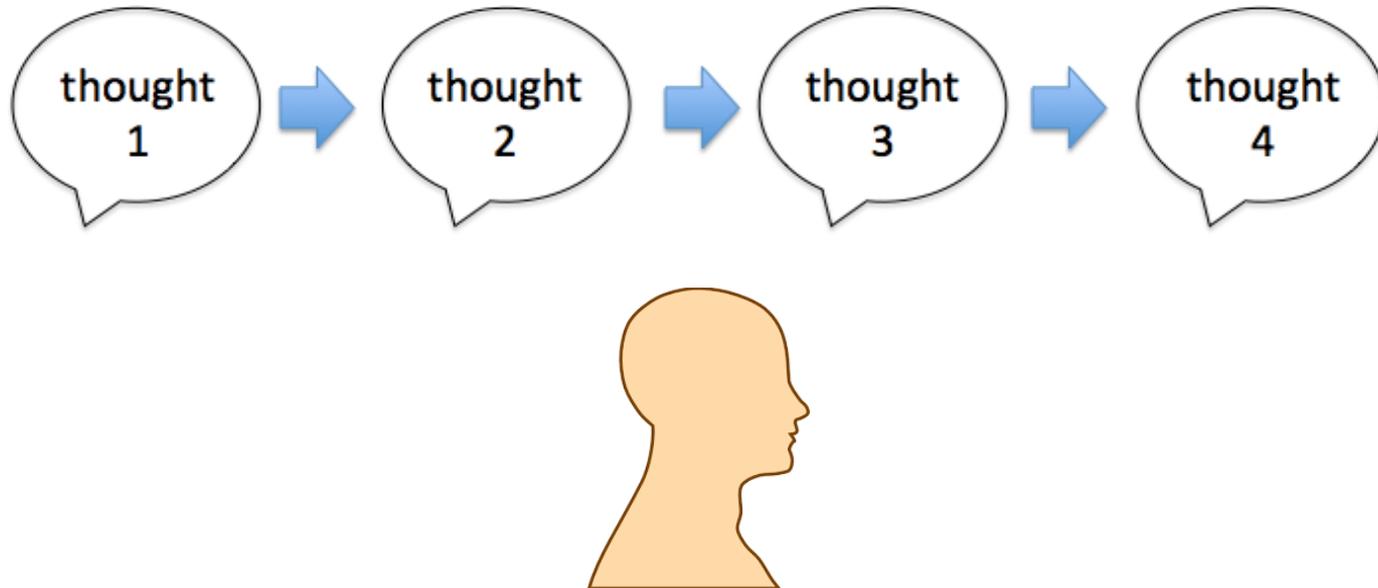


# The Spontaneous Mind: Wandering Into the Future

Chandra Sripada  
Department of Psychiatry,  
Department of Philosophy  
University of Michigan, Ann Arbor

**Suppose you are sitting on a bus wide awake. It is dark.  
There isn't anyone near you.**

**Is your mind completely quiet?**



**spontaneous stream of thought = “mind wandering”**

The spontaneous stream of thought is not a new discovery...

## Siddhartha Gautama Buddha



“mind is monkey”

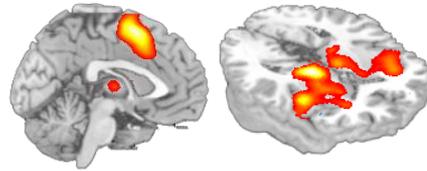
developed meditative techniques to  
manage the wandering mind

# The Cognitive Science of Thinking

## Serial Thought

A sequence of connected thoughts

Conscious,  
Intentional, Effortful  
Controlled/Directed  
**system 2 thinking**

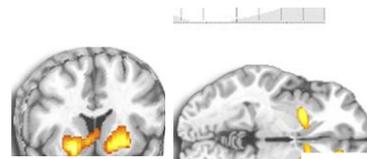


## Singleton Thought

A single thought "pops" into your mind

**system 1 thinking**

Fast, Automatic, Effortless

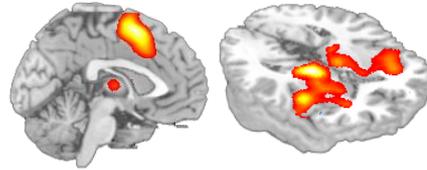


# The Cognitive Science of Thinking

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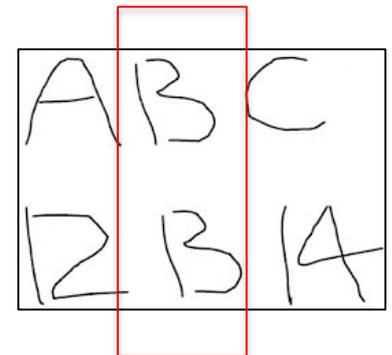
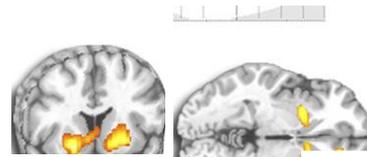


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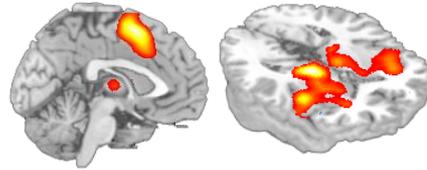


# The Cognitive Science of Thinking

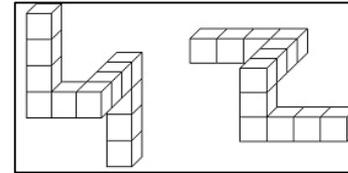
## Serial Thought

A sequence of connected thoughts

Conscious,  
Intentional, Effortful  
Controlled/Directed  
**system 2 thinking**



$$\begin{array}{r} 2473 \\ + 3935 \\ \hline \end{array}$$

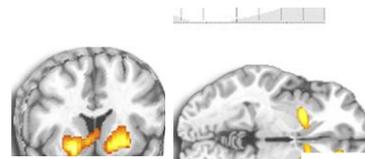


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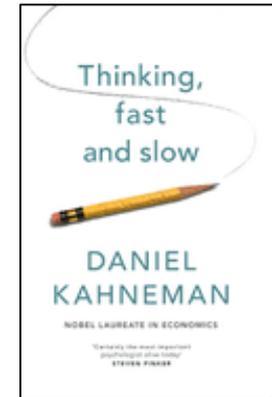
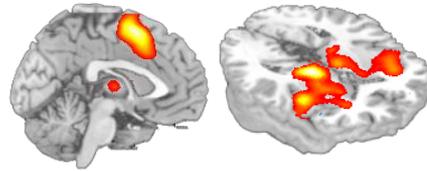


# The Cognitive Science of Thinking

## Serial Thought

A sequence of connected thoughts

Conscious, Intentional, Effortful Controlled/Directed  
**system 2 thinking**



## Singleton Thought

A single thought "pops" into your mind

**system 1 thinking**

Fast, Automatic, Effortless

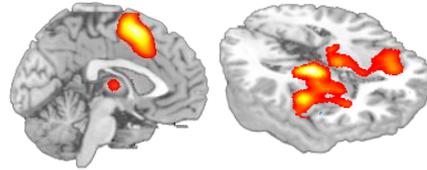


# The Cognitive Science of Thinking

## Serial Thought

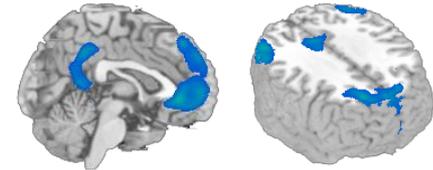
A sequence of connected thoughts

Conscious,  
Intentional, Effortful  
Controlled/Directed  
**system 2 thinking**



Conscious,  
Unintentional, Effortless  
Discursive

**spontaneous stream  
of thought**



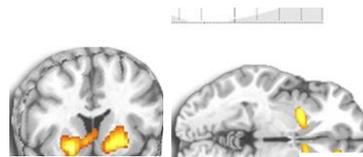
**“The Forgotten  
Third Mode of  
Thinking”**

## Singleton Thought

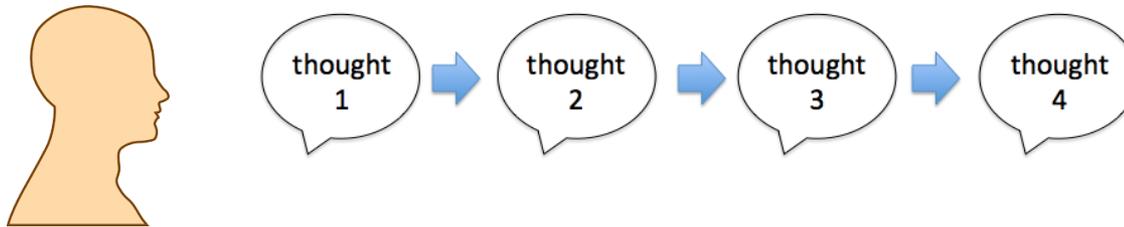
A single  
thought "pops"  
into your mind

**system 1 thinking**

Fast, Automatic, Effortless



# Why should you care about the spontaneous stream of thought?

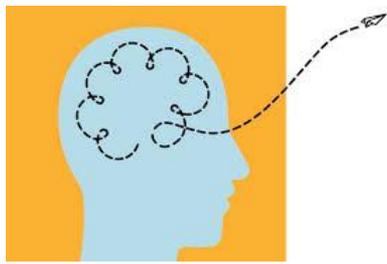


## The spontaneous stream of thought is highly intimate

It flows from the person's "self" – their goals, concerns, and evaluations

## The spontaneous stream of thought is altered in highly characteristic ways in mental disorders

- depression
- social anxiety
- ADHD
- bipolar disorder



Mind wandering/the spontaneous stream of thought are “hot” in cognitive neuroscience and psychiatry.

# Experience Sampling Methodology



some studies say 30-50% of our waking lives is spent mind wandering

We do a LOT of mind wandering!!

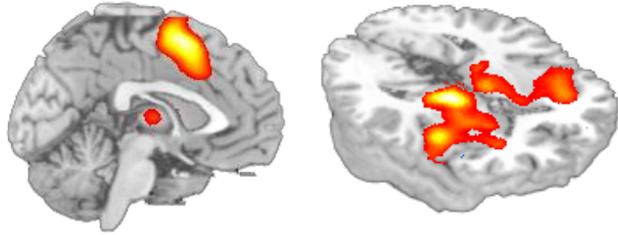
Baumeister, R. F., Hofmann, W., & Vohs, K. D. (2015). Everyday thoughts about the past, present, and future: An experience sampling study of mental time travel. Manuscript submitted for publication.

Killingsworth MA, Gilbert DT. A wandering mind is an unhappy mind. *Science* 2010; 330: 932.

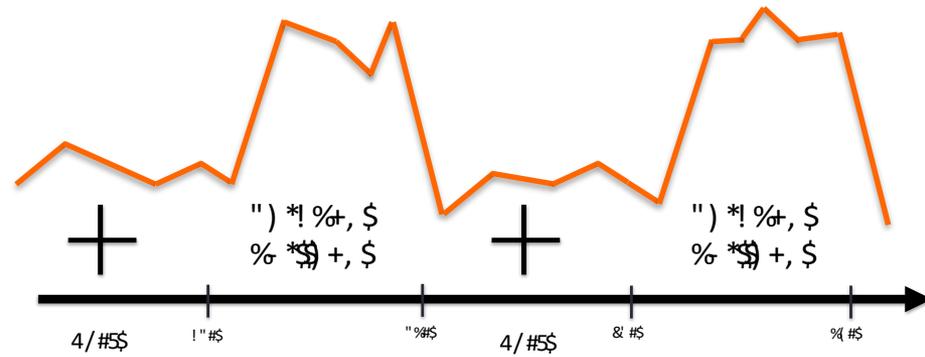
Kane MJ, Brown LH, McVay JC, Silvia PJ, Myin-Germeys I, Kwapil TR. For Whom the Mind Wanders, and When An Experience-Sampling Study of Working Memory and Executive Control in Daily Life. *Psychol Sci* 2007; 18: 614–621.

Klinger E, Cox WM. Dimensions of Thought Flow in Everyday Life. *Imagin Cogn Personal* 1987; 7: 105–128.

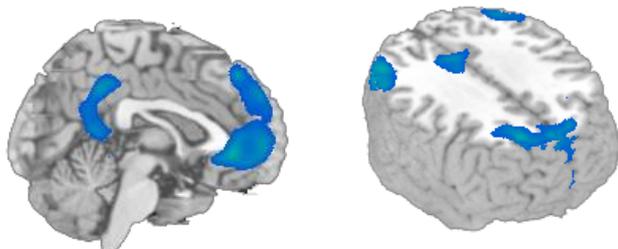
# The Discovery of the Default Network



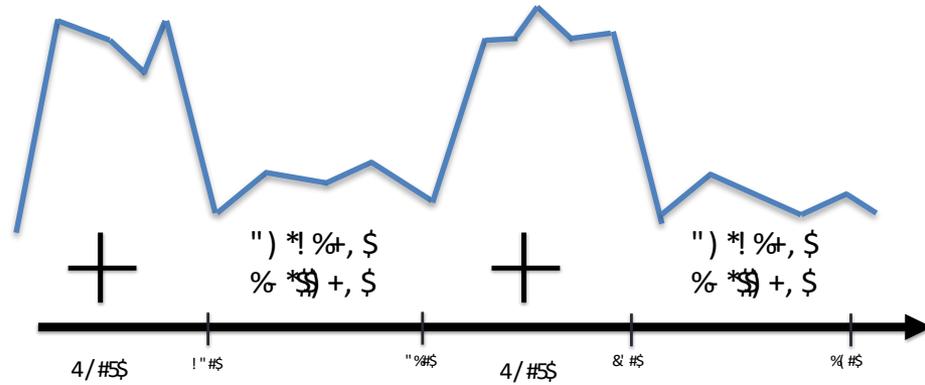
Task-positive regions



The task positive network is the substrate for directed system 2 thinking

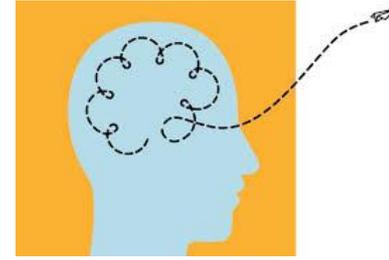


Default Regions

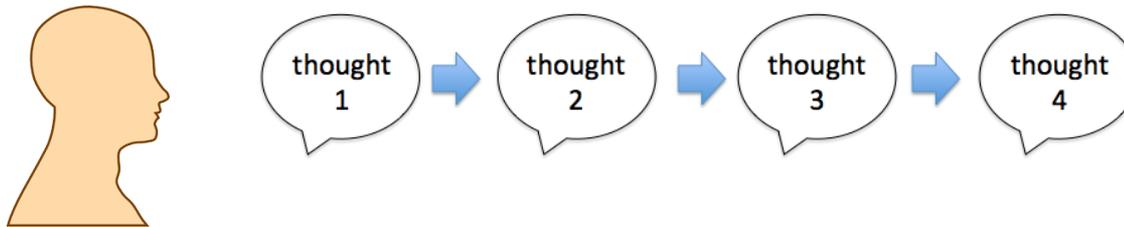


The default network is the substrate for mind wandering

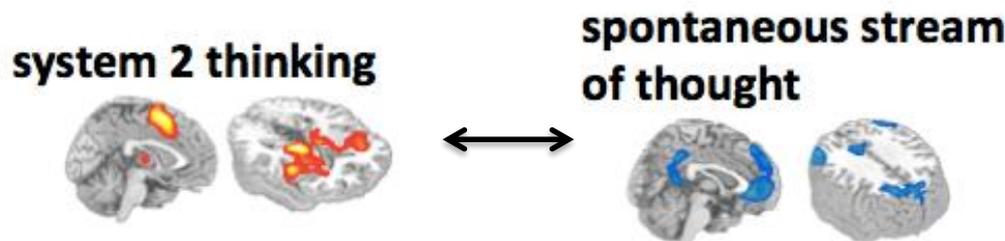
# Two Central Questions about the Spontaneous Stream of Thought

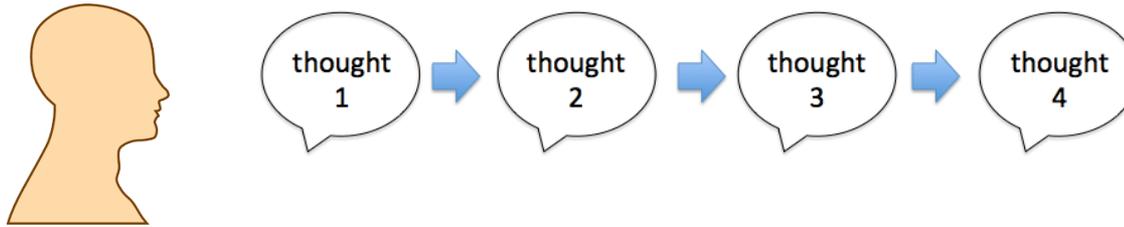


1. **Mechanism Question:** How do spontaneous thoughts get “stitched” together into a sequence?



2. **Regulation Question:** How does the mind regulate switches between goal-directed system 2 thinking and spontaneous thinking?





How do you study spontaneous thought?

--essentially private

--if you probe it, you disturb it

# Our approach



## “Talk Aloud” Methodology

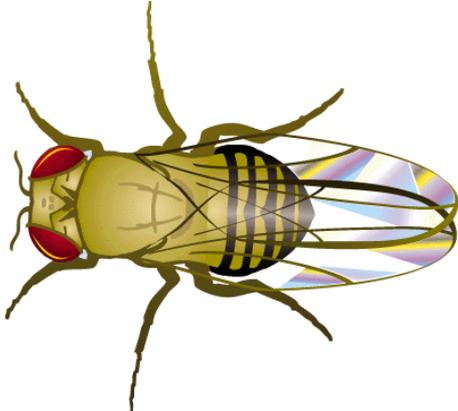
subjects are alone in a dark, quiet room

narrate their spontaneous thoughts for  
30 minutes

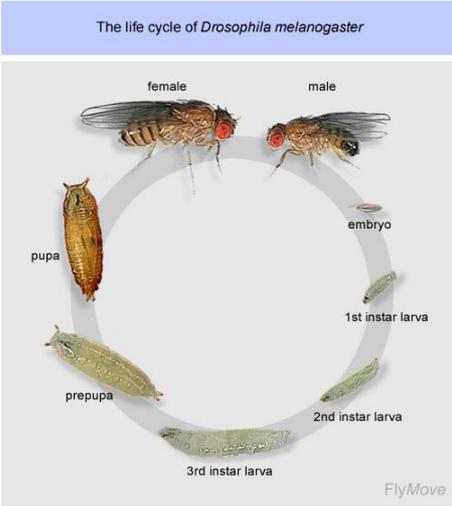
we transcribe their thoughts, sentence by  
sentence

30 subjects, 15 thousand lines of thoughts!

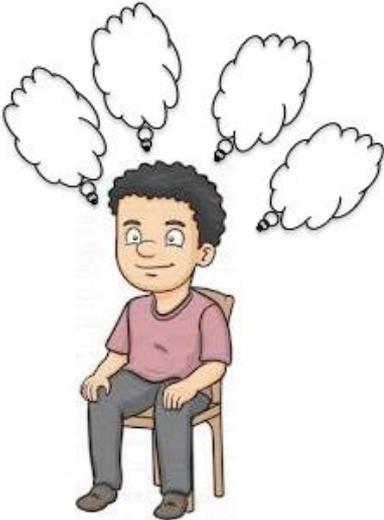
Fruit fly systems are quite different than human systems



Drosophila  
Melanogaster



But, we can still use fruit fly systems to illuminate causal processes that go on in human systems



Similarly, we can use “talk aloud” spontaneous thoughts to illuminate causal processes that go on in “silent” spontaneous thoughts

## Snippet of Subject's Data

The family is going to come up for my birthday

It's coming up.

It'll be nice to see my sister, my mom and I don't think my dad's coming.

I have to make sure to clean up the house

Make it look nice for them.

I'll do it this weekend.

I want to try to wake up earlier so that I will have more time.

There is never enough time these days.

Too rushed.

Get home and have to make dinner

Barely time to watch TV

I never catch up with Name1 and Name2 anymore

So much worse with my new job.

Why does everyone suck?

Looking out for themselves – so superficial.

When I was in high school, I promised myself I'd never be like that...

Wanted to be a rapper in high school – ya right

That went down in flames

The room is too cold

I wish I had brought my jacket

Back is sore from shivering

## Snippet of Subject's Data

The family is going to come up for my birthday

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That went down in flames

---

The room is too cold

I wish I had brought my jacket

Back is sore from shivering

## Snippet of Subject's Data

### Topic

<i>Family coming for birthday</i>	<p>The family is going to come up for my birthday It's coming up. It'll be nice to see my sister, my mom and I don't think my dad's coming. I have to make sure to clean up the house Make it look nice for them. I'll do it this weekend.</p> <hr/>
<i>I don't have enough time</i>	<p>I want to try to wake up earlier so that I will have more time. There is never enough time these days. Too rushed. Get home and have to make dinner Barely time to watch TV I never catch up with Name1 and Name2 anymore So much worse with my new job.</p> <hr/>
<i>People suck, high school</i>	<p>Why does everyone suck? Looking out for themselves – so superficial. When I was in high school, I promised myself I'd never be like that... Wanted to be a rapper in high school – ya right That went down in flames</p> <hr/>
<i>Room is too cold</i>	<p>The room is too cold I wish I had brought my jacket Back is sore from shivering</p>

## Snippet of Subject's Data

### EPIISODES

### IDEAS

1

- 1 The family is going to come up for my birthday
  - 2 It's coming up.
  - It'll be nice to see my sister, my mom and I don't think my dad's coming.
  - I have to make sure to clean up the house
  - Make it look nice for them.
  - n* I'll do it this weekend.
- 

2

- 1 I want to try to wake up earlier so that I will have more time.
  - 2 There is never enough time these days.  
Too rushed.
  - Get home and have to make dinner
  - Barely time to watch TV
  - I never catch up with Name1 and Name2 anymore
  - n* So much worse with my new job.
- 

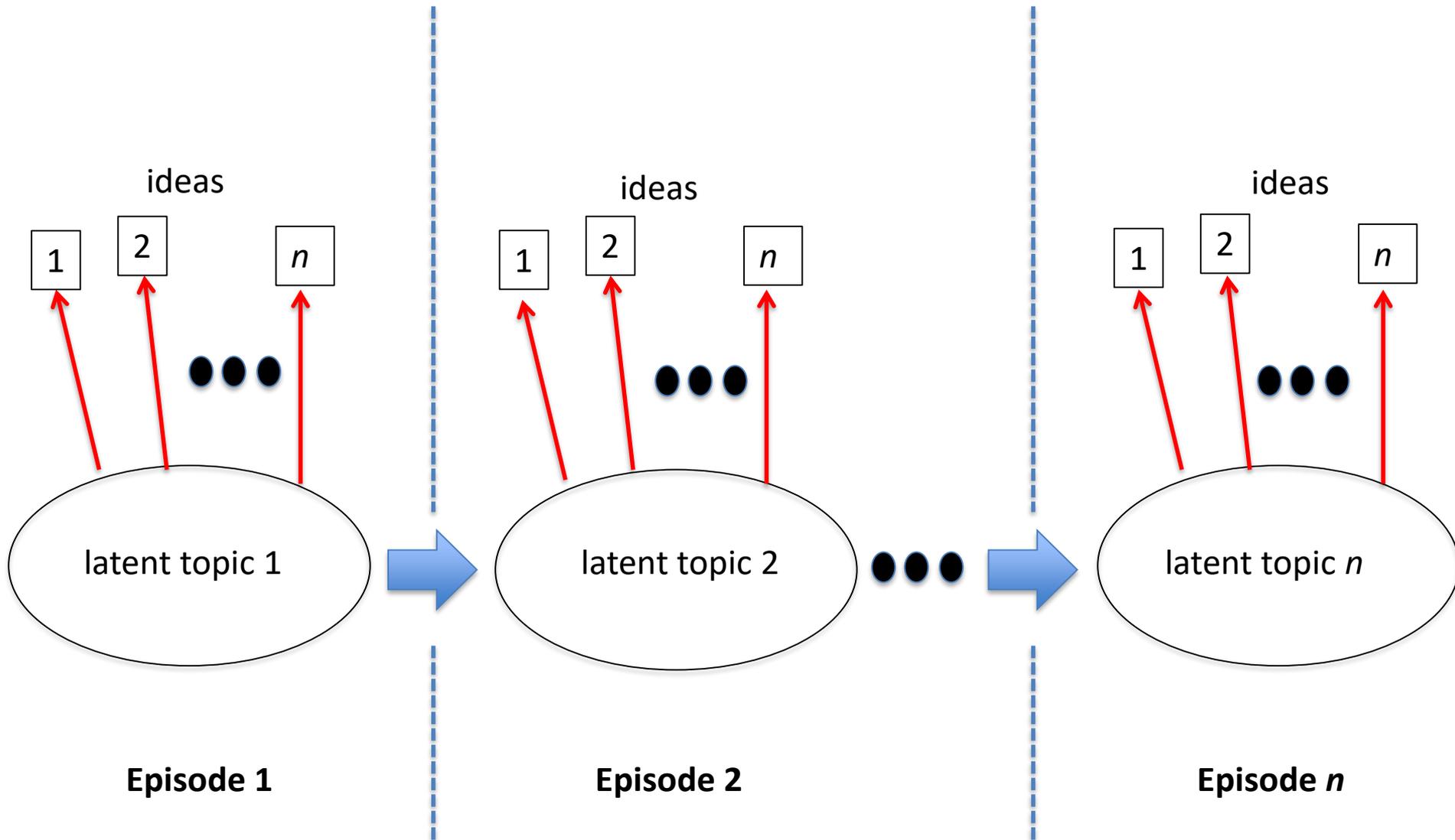
3

- 1 Why does everyone suck?
  - 2 Looking out for themselves – so superficial.
  - When I was in high school, I promised myself I'd never be like that...
  - Wanted to be a rapper in high school – ya right
  - n* That went down in flames
- 

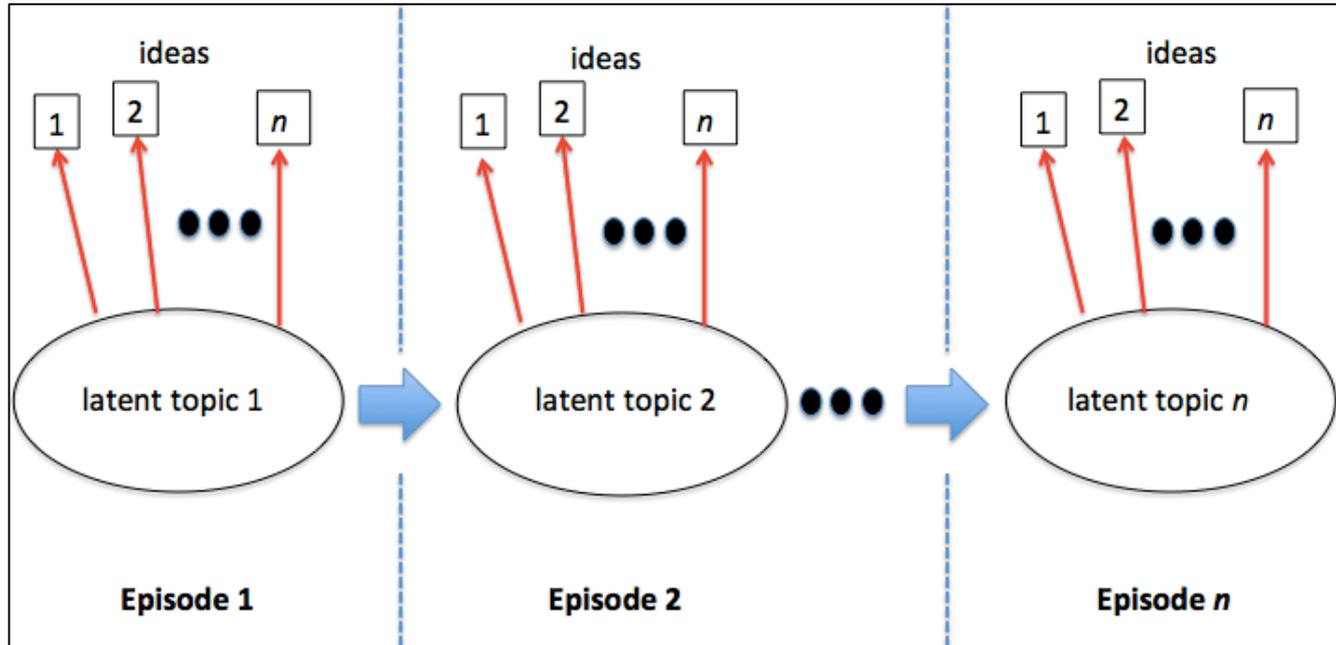
4

- 1 The room is too cold
- 2 I wish I had brought my jacket
- 3 Back is sore from shivering

# “Topic Hopping” Model of the Spontaneous Stream of Thought



# Topic Hopping Model of the Spontaneous Stream of Thought



How can we test this model?

Are the breaks reliable? Do different raters agree on where the breaks are?

	A	B	C	D	E	F	G	H	I	J	K	L
1	Subject	Index_AE	Index_SF	Index_SR	Index_Sum	Thoughts						
2	50	0	0	0	0	0 It sounds like the air conditioner in the lounge						
3	50	0	1	0	1	1 This shirt is really soft						
4	50	1	1	0	3	3 I can probably meditate to this white noise sound						
5	50	1	0	1	3	3 That's a really old phone, it looks ancient						
6	50	0	1	0	1	1 Well not that ancient						
7	50	0	0	0	0	0 The one in my house is worse						
8	50	1	1	1	3	3 I wonder how many people actually use that phone						
9	50	1	1	1	3	3 I wonder what the blue light on the ceiling thing is						
10	50	0	0	0	0	0 It might be a fire alarm I'm not totally sure						
11	50	1	0	1	2	2 I can't wait to get a cat next year						
12	50	1	0	1	2	2 I need to find a seventh roommate though						
13	50	1	1	1	3	3 And get lots of plants						
14	50	1	1	1	3	3 I like plants						
15	50	1	0	1	2	2 I think I might get some empty wine bottles and put plants in them						
16	50	1	1	1	3	3 And have a nice little rack in the living room with a bunch of plants in wine bottles						
17	50	0	0	0	0	0 If I put them in the plants or vines it'd be like spilled wine which is a beautiful						
18	50	0	0	0	0	0 Just staring at the ceiling right now						
19	50	0	0	1	1	1 I wonder if I can hang stuff on the ceiling						
20	50	1	1	1	3	3 The lounge's ceilings are all messed up they're similar						
21	50	0	0	0	0	0 But you can't set the tiles back in easily						
22	50	0	0	0	0	0 People hang balloons on them						
23	50	0	0	0	0	0 I wonder if I can hang balloons on the ceiling in the house next year, that'd be fun						
24	50	0	1	0	1	1 Does my house have overhead lighting						
25	50	0	0	0	0	0 I can't remember						
26	50	0	0	1	1	1 Maybe I'll just do fairy lights or something if it doesn't, whatever works						
27	50	1	1	0	2	2 I can't wait to cook						
28	50	0	0	0	0	0 Just had chaparadda yesterday and it was so good, make more of that stuff						
29	50	1	1	1	3	3 I miss Chicago						
30	50	1	0	1	3	3 Mexican food is so good you can't get that here						
31	50	0	0	1	1	1 It's all gentrified, mediocre, and expensive crap						
32	50	1	0	0	1	1 Ugh, I wanna make stuff						
33	50	0	0	0	0	0 I miss making stuff from home, baker's feast						
34	50	0	0	0	0	0 Though I do have work on Friday at the baker's feast						
35	50	0	0	0	0	0 I could probably make stuff then						
36	50	0	0	0	0	0 I need to make the bean [unintelligible], making a t-shirt box holder						
37	50	0	0	0	0	0 I've been meaning to do that for a while						
38	50	0	0	0	0	0 I have to get filament dough						
39	50	0	0	1	3	3, I guess I'll probably use some of that [playfilm						

Intra-class correlation is 0.61!!

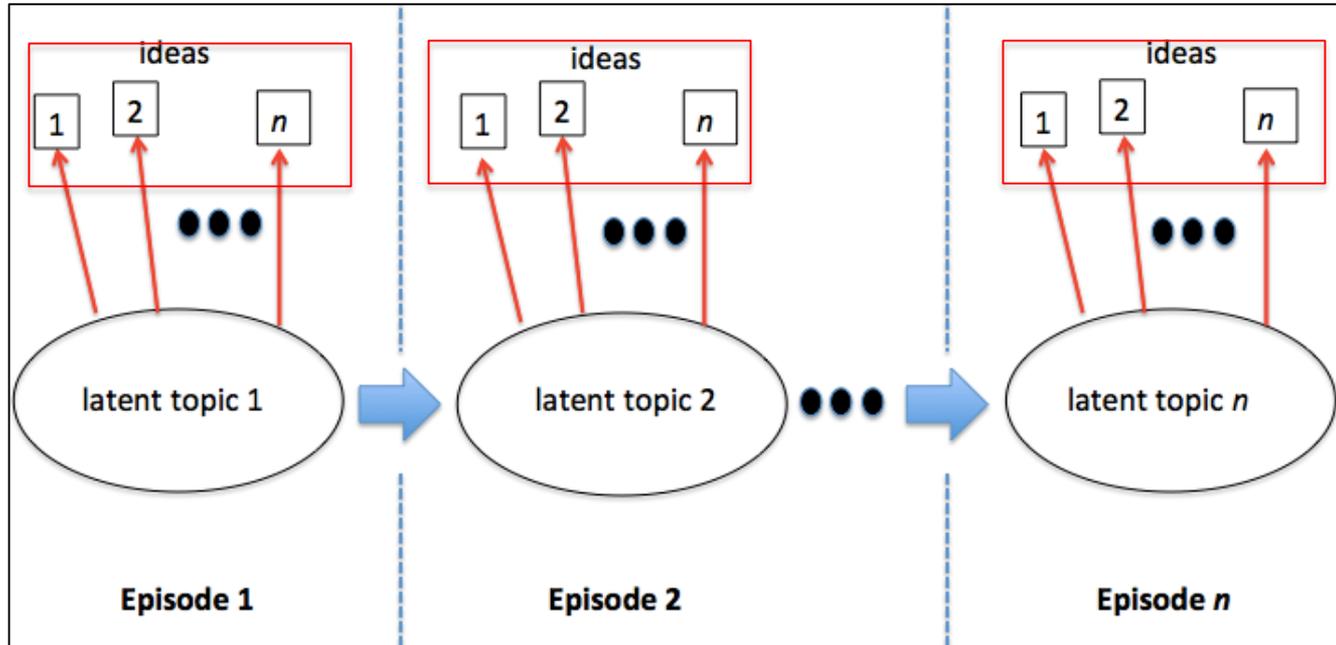
# Latent Semantic Analysis

a method that uses co-occurrence of words in massive corpuses of texts to quantify the associative strength between pairs of sentences.

*automated and objective*

going to the movies is fun	}	0.75	0 is no similarity 1 is perfectly similar
watching the actors and actresses makes me happy			
going to the movies is fun	}	0.36	
the dog and the cat played in the yard			

# Topic Hopping Model of the Spontaneous Stream of Thought

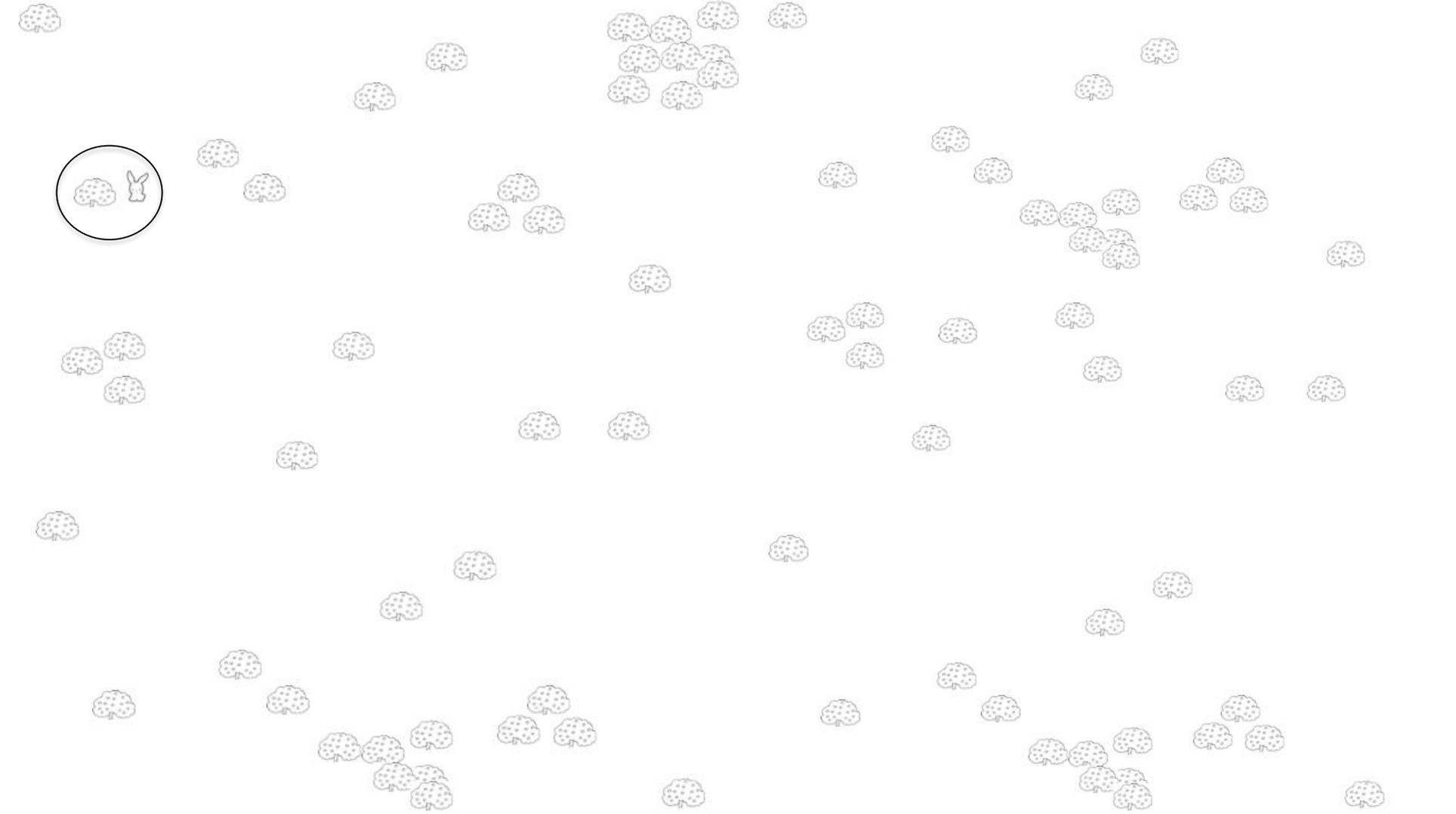


Is the associative strength within an episode higher than the associative strength between episodes?

Yes!!

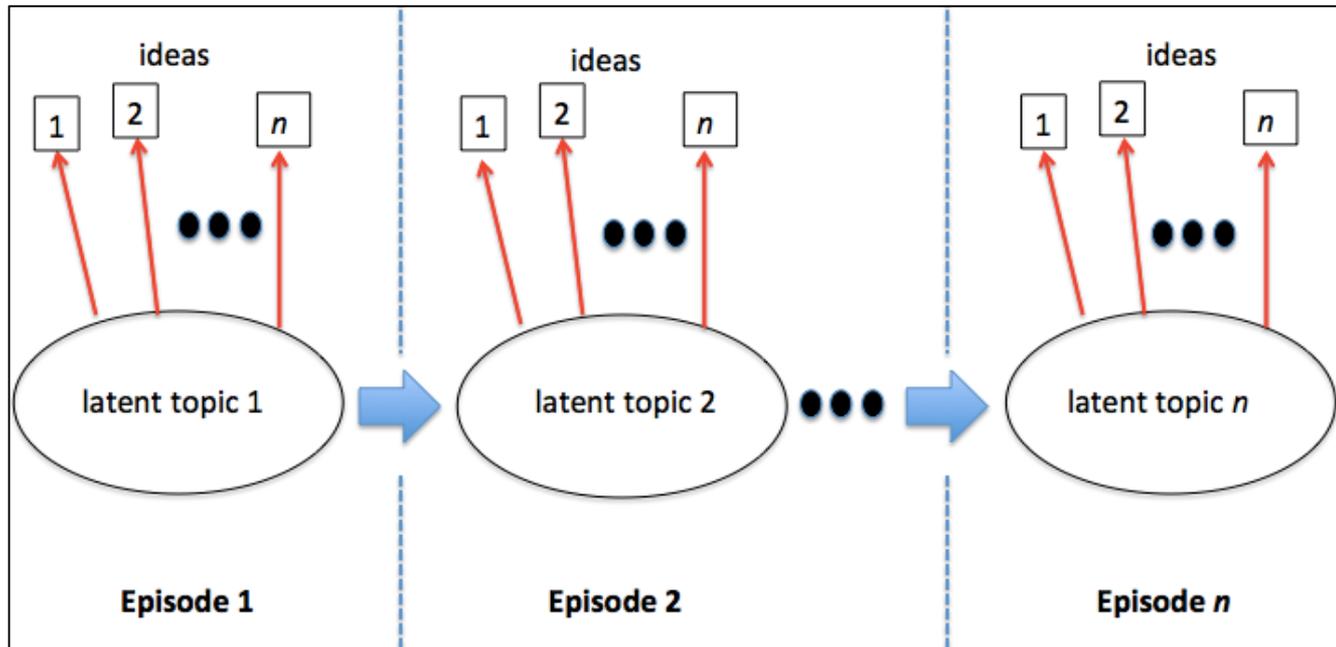
mean within episode similarity: 83  
mean between episode similarity: 67

$p=0$





# Topic Hopping Model of the Spontaneous Stream of Thought



During the spontaneous stream of thought, people are all topic hopping.

But do they all hop around to similar topics?

**No!**

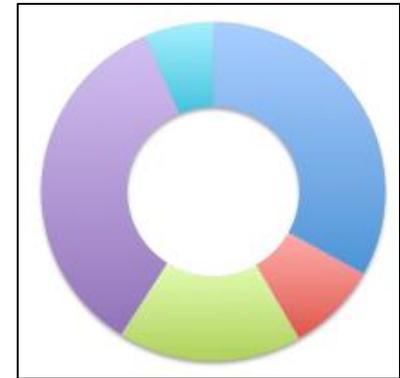
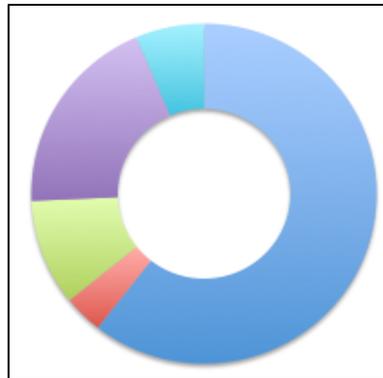
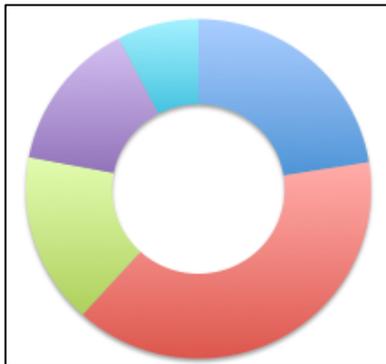
## Across All Subjects

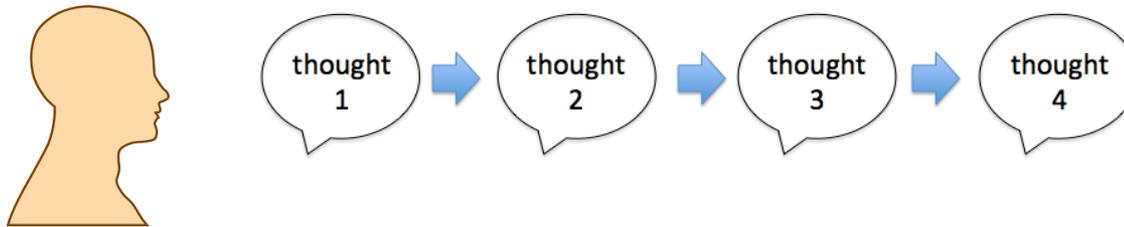
### Coding of Episodes

- Goals/Concerns
- Immediate Environment
- Past Events
- Evaluations
- None of the above



### Three individual subjects...

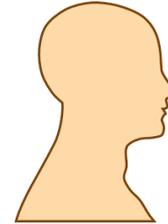
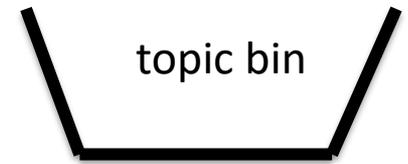
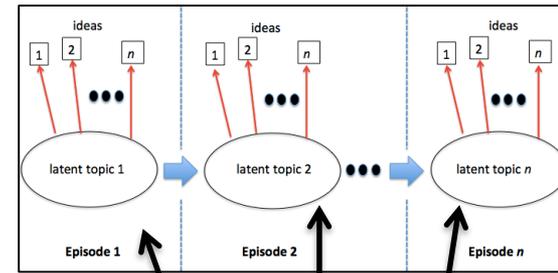
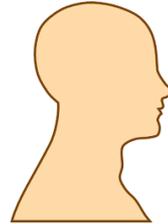
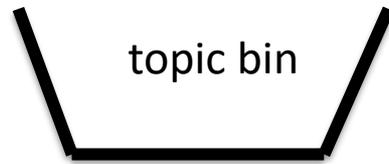
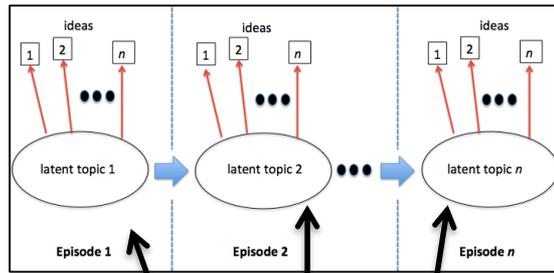
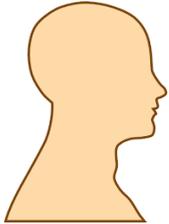
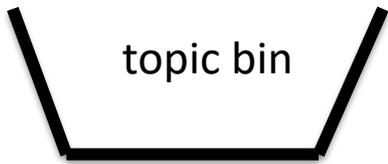
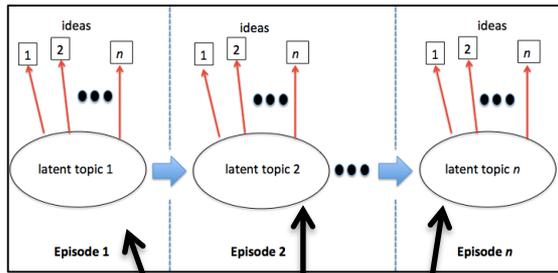




All subjects completed personality questionnaires and psychological scales.

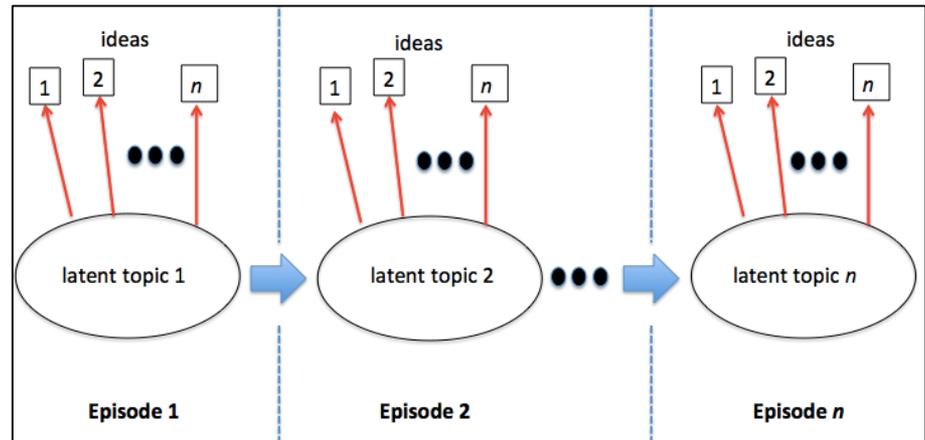
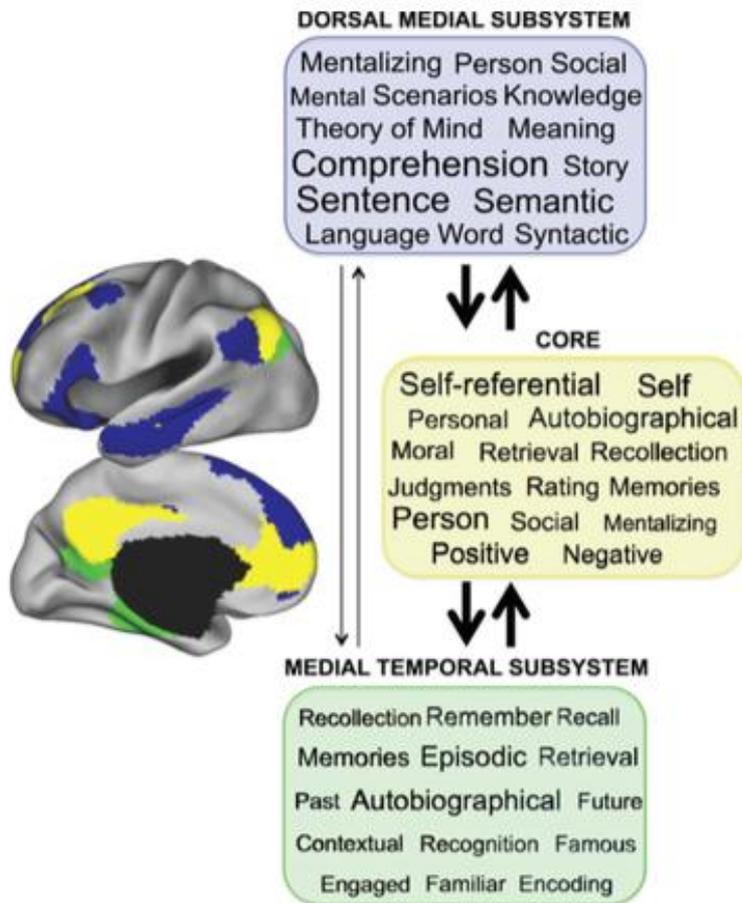
We performed automated sentiment analysis, which assigns each person a score on a range of affective dimensions.

People with higher levels of neuroticism have detectably higher levels of sad and anxious sentiments in their spontaneous thoughts

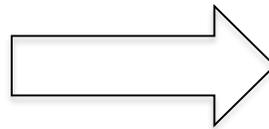
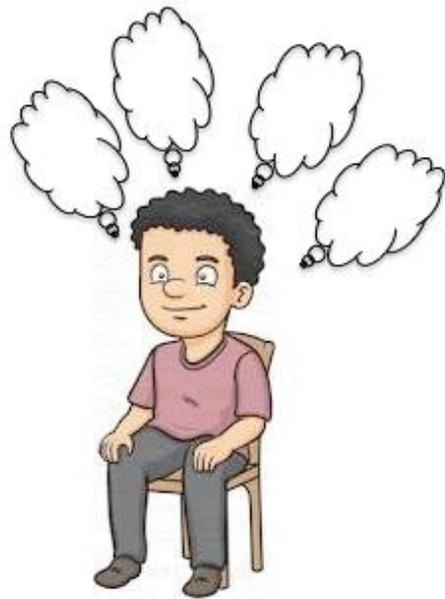


Each topic bin reflects the person's own distinctive goals, concerns, experiences....

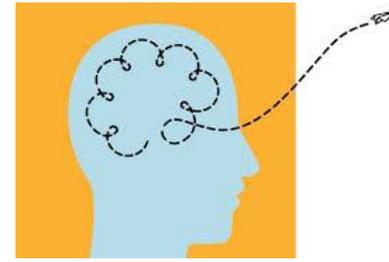
# The “Parts” of the Default Network Fit Nicely With the Topic Hopping Model



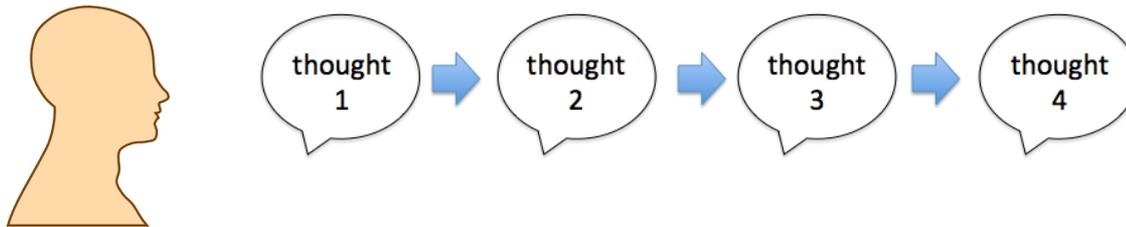
**Coming Attractions: We will conduct our talk aloud protocol in the fMRI scanner this summer...**



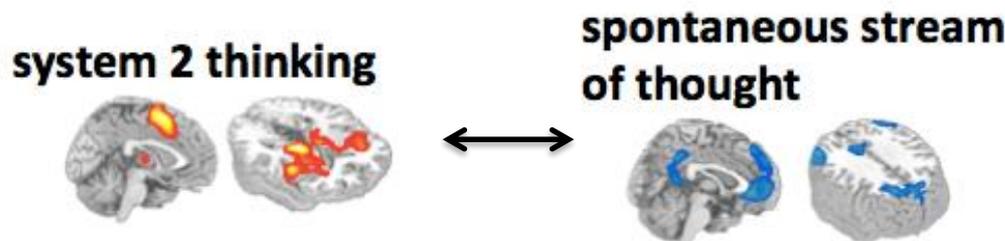
# Two Central Questions about the Spontaneous Stream of Thought



1. **Mechanism Question:** How do spontaneous thoughts get “stitched” together into a sequence?



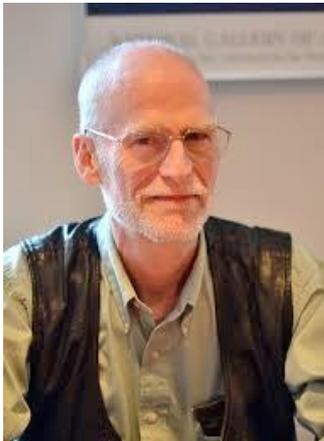
2. **Regulation Question:** How does the mind regulate switches between goal-directed system 2 thinking and spontaneous thinking?



**Do you actively control your spontaneous thoughts?**

**OR**

**Do they occur automatically, i.e., they just happen to you?**



Peter Carruthers  
active control!

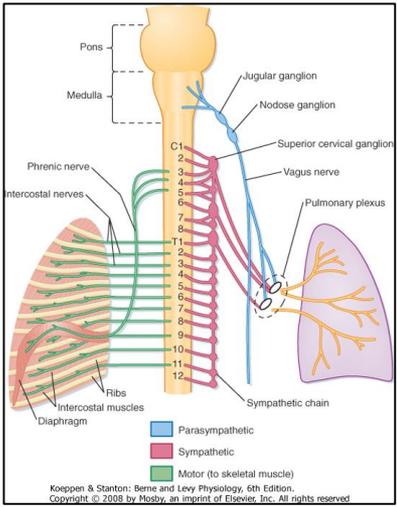


Thomas Metzinger  
automatic!

# Dual Control Over Breathing

brain stem “pacemaker” and autonomic nervous system

provide automatic ongoing drive to breath



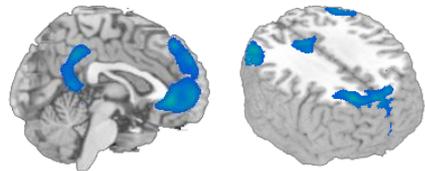
motor innervation of diaphragm, intercostals

provide ability to control and modulate automatic drive to breath

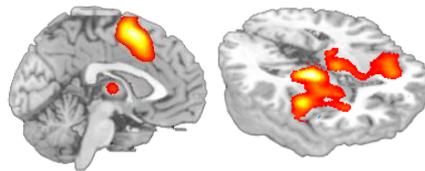
# Dual Control Over the Stream of Thought

default network

provides automatic ongoing drive to mind wander



default network

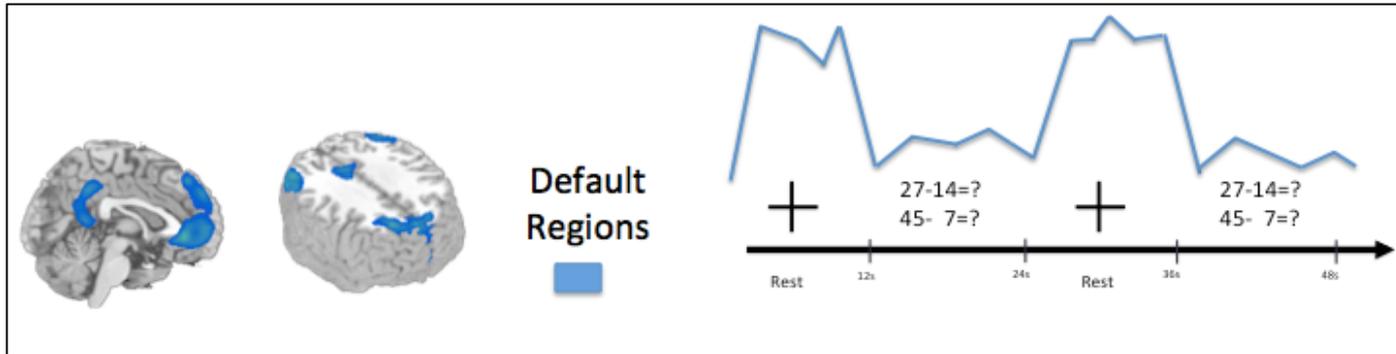


“system 2” networks

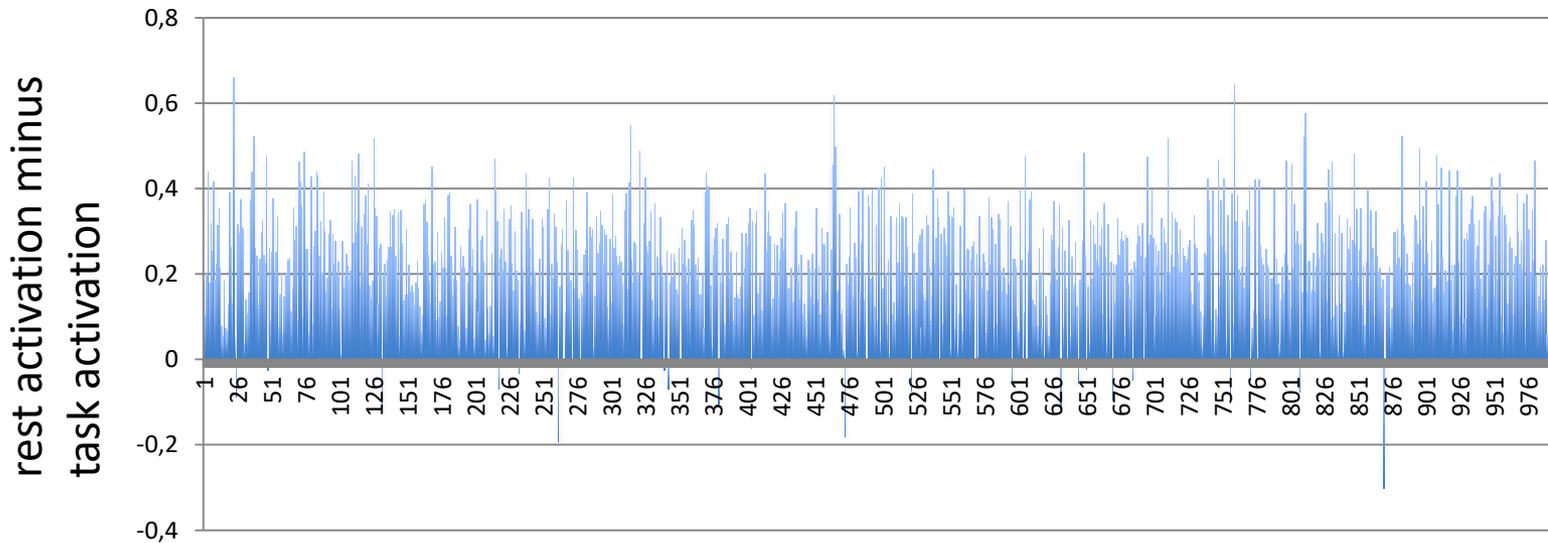
system 2 networks

provide ability to control and modulate automatic drive to mind wander

# Evidence for a passive, automatic drive to mind wander



997 subjects completed blocks of working memory task and blocks of rest  
963 show more activation in default mode network at rest



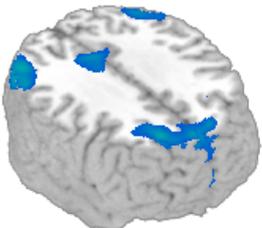
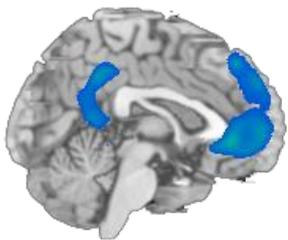
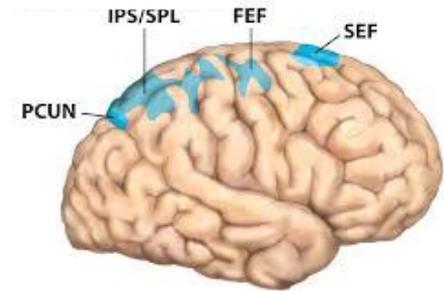
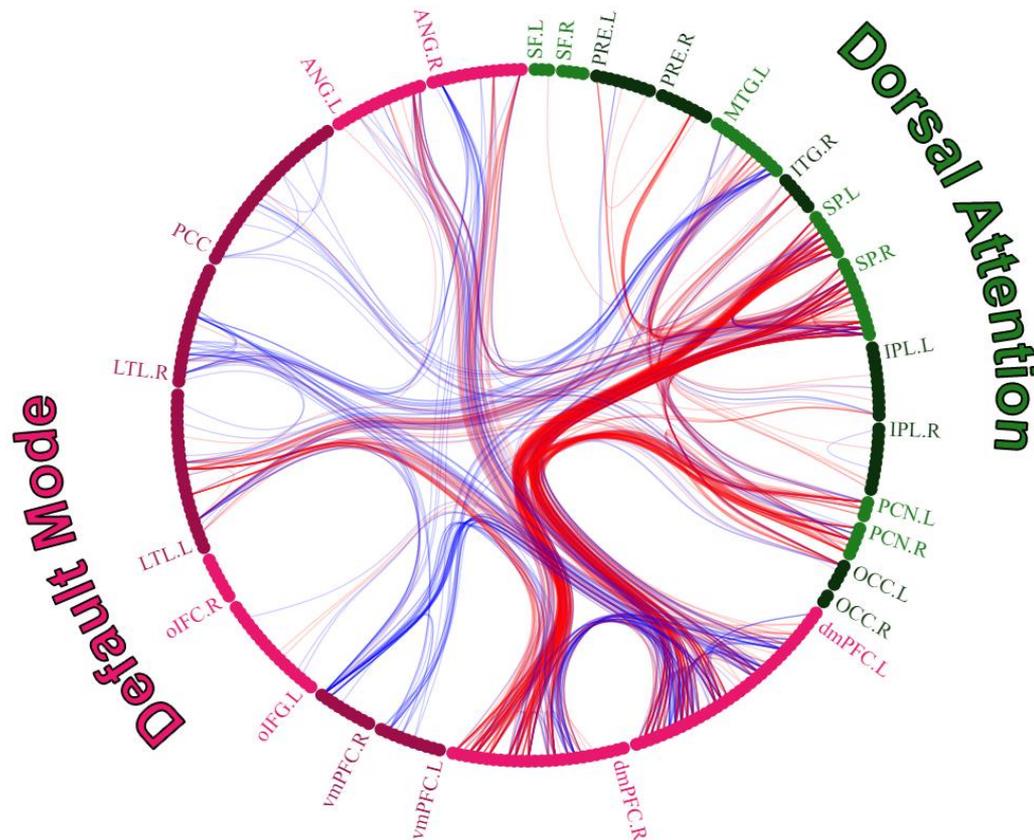
**As soon as a demanding task ends, the mind “automatically” turns to the spontaneous stream of thought**

# Evidence for a voluntary ability to control mind wandering

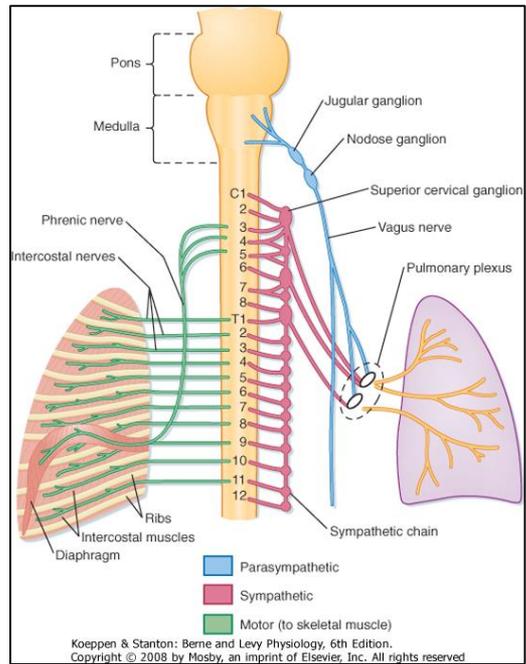


All subjects (N=52) did one session of regular “unconstrained” rest and one session of “mindful” rest where they concentrated on their breath.

## Mindful Rest > Unconstrained Rest



# Breathing Analogy



automatic ongoing drive to breath

plus

ability to control and modulate automatic drive to breath

It is obvious why we have an automatic ongoing drive to breath

We need the oxygen!

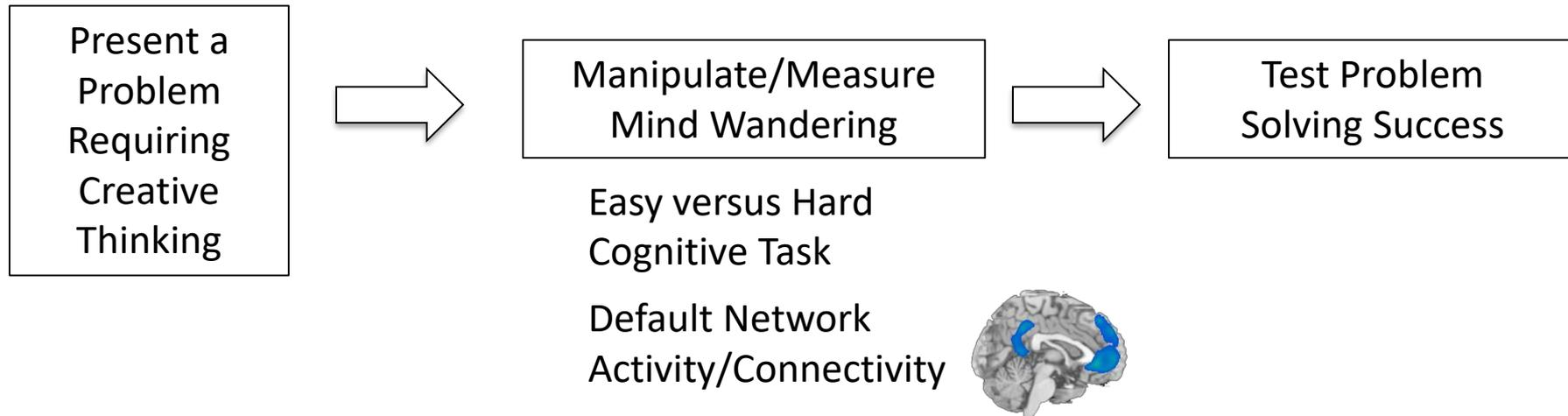
Why would we have an automatic ongoing drive to mind wander? What benefit does it serve?

Mind wandering enhances “pattern discovery” and creativity

**Individuals who mind wander have better social relatedness and creativity**

*Pure Correlational Studies* Singer and Schonbar, 1961; Singer, 1964; Singer, 1966, 1974, 1975, 1993, 2009; Wang et al., 2009; Baars, 2010; Baird et al., 2011, 2012; Kaufman and Singer, 2011; Stawarczyk et al., 2011; Kaufman, 2013

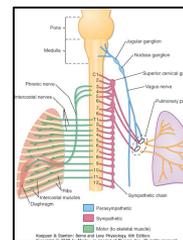
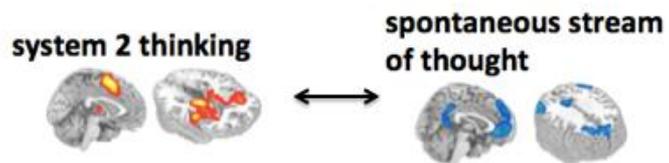
*Studies with manipulations* **Manipulations that promote mind wandering promote social processing and creativity**



*Behavioral studies* Baird et al (2012)

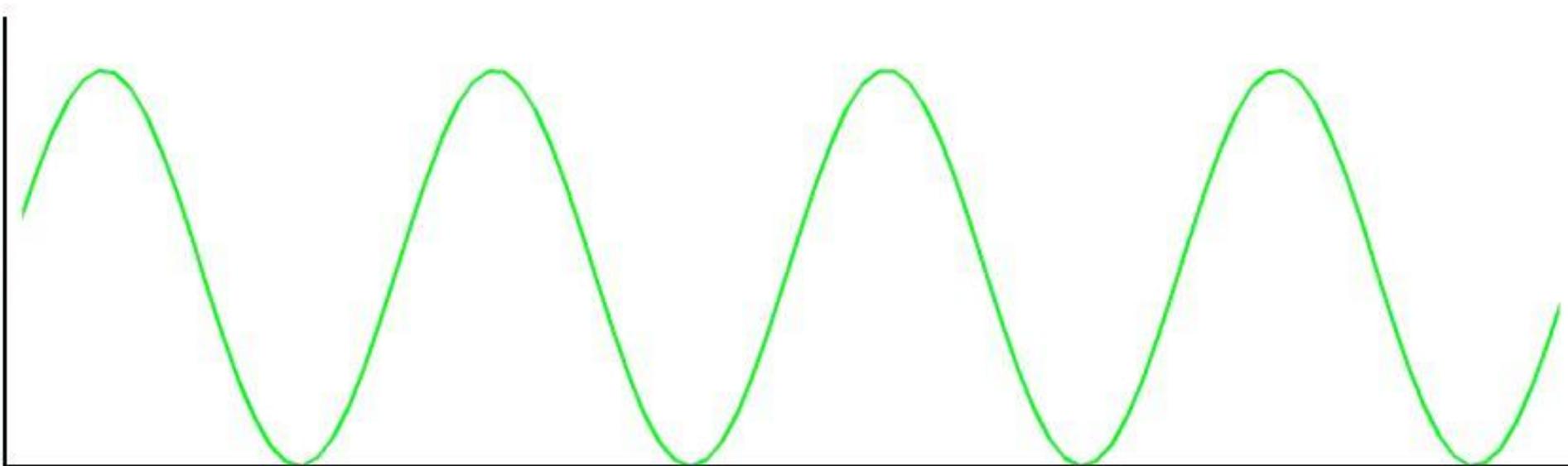
*Studies with fMRI* Immordino-Yang et al. 2012 (parsing social events)  
Takeuch et al 2011 (divergent thinking challenge)  
Wang et al 2009 (spatial navigation task)

**2. Regulation Question:** How does the mind regulate switches between goal-directed system 2 thinking and spontaneous thinking?



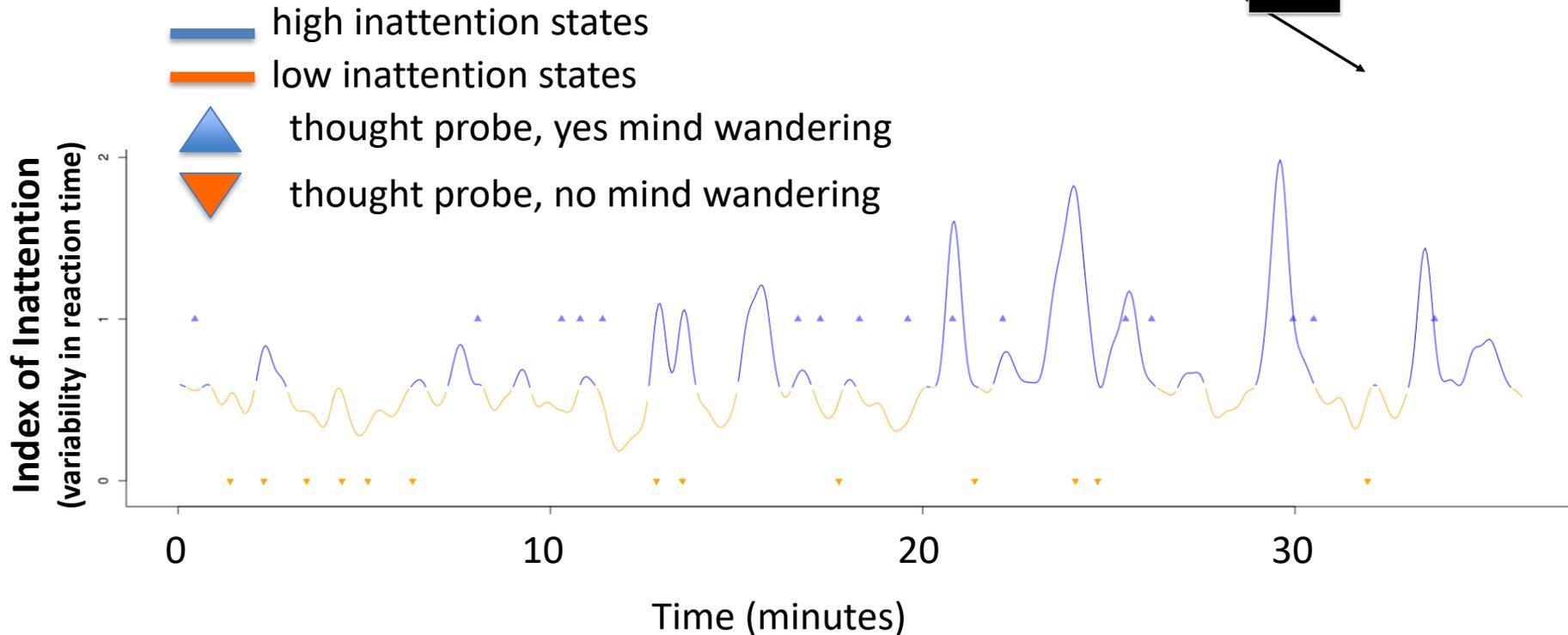
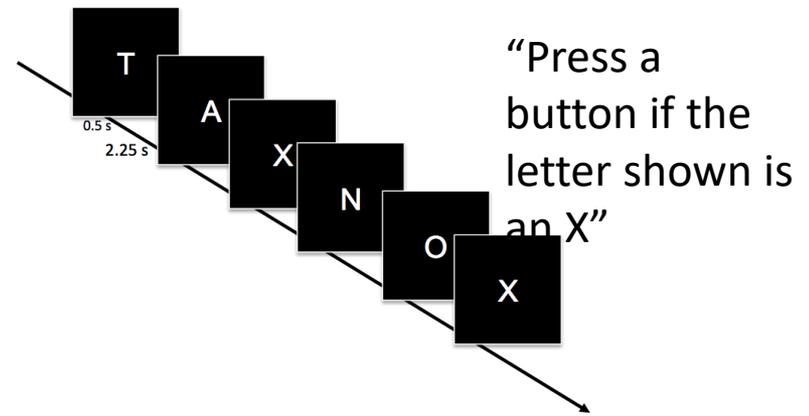
Breathing Analogy  
Combines  
Automaticity and  
Control

## The Fluctuation of Attention Over Time

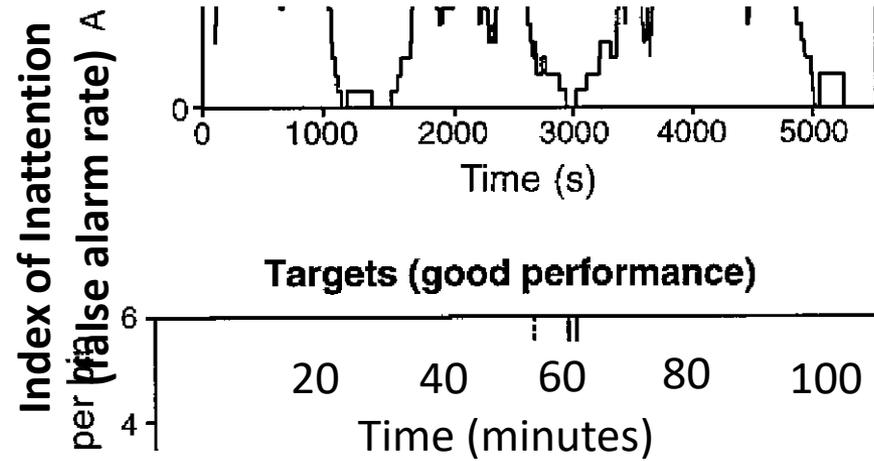
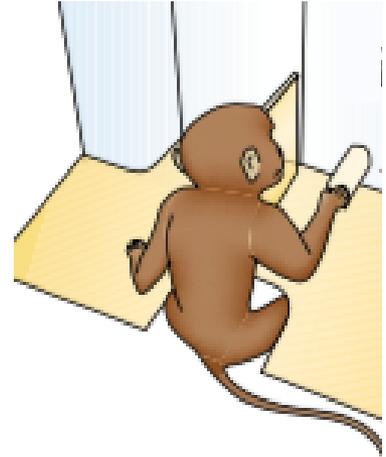


# Sustained Attention Response Task (SART)

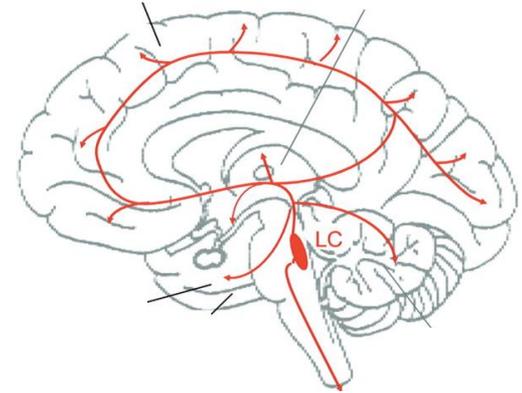
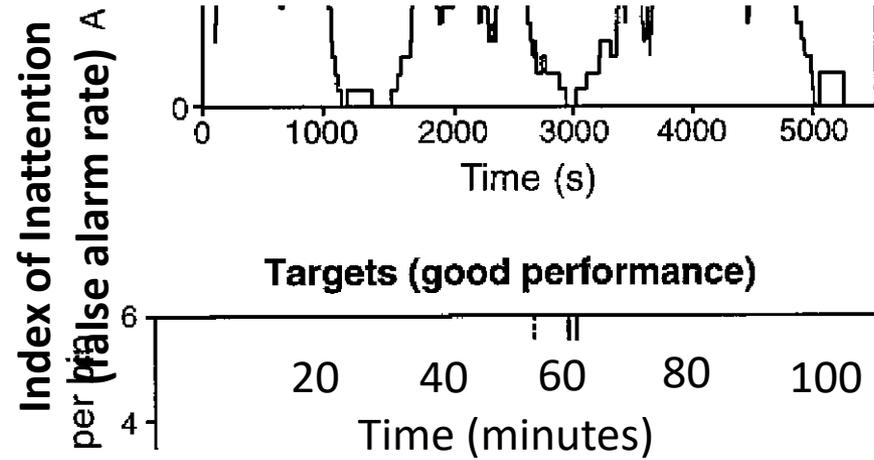
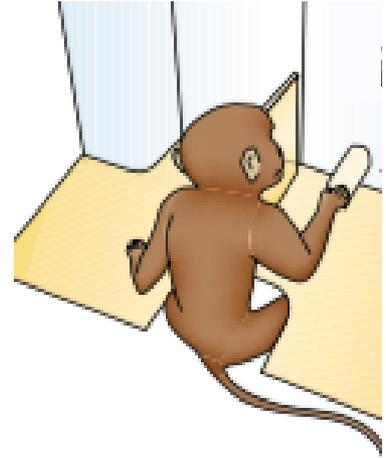
Mind wandering and directed thinking oscillate in a quasi-periodic pattern



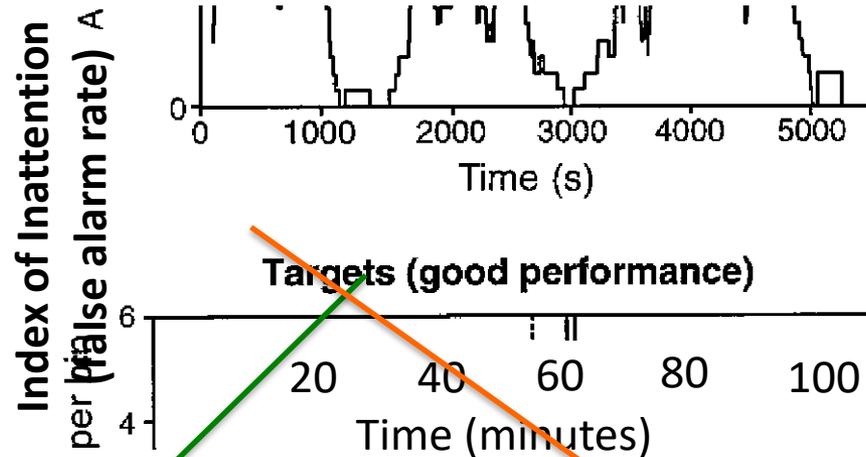
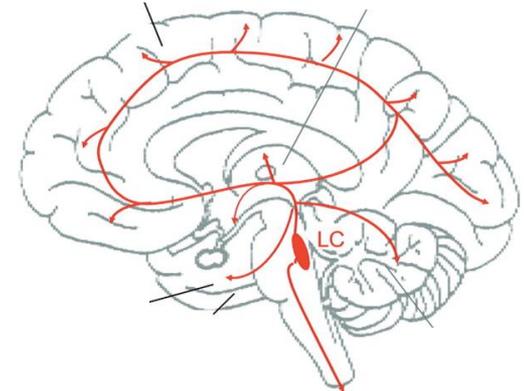
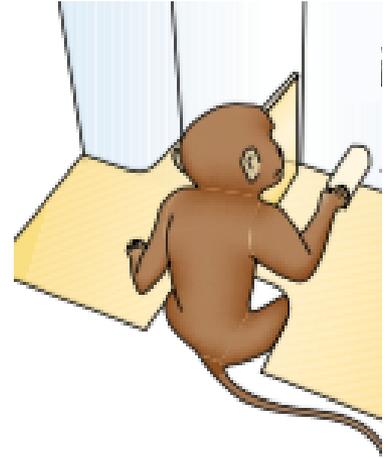
The locus coeruleus, a midbrain structure, helps to regulate switching from mind wandering to directed thinking



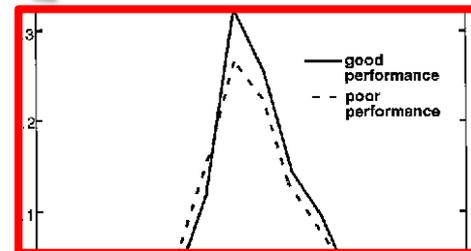
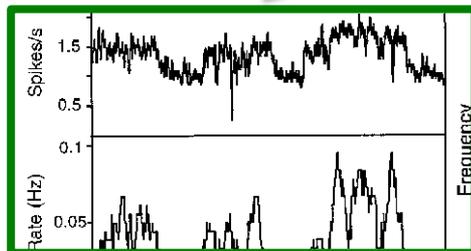
The locus coeruleus, a midbrain structure, helps to regulate switching from mind wandering to directed thinking



The locus coeruleus, a midbrain structure, helps to regulate switching from mind wandering to directed thinking

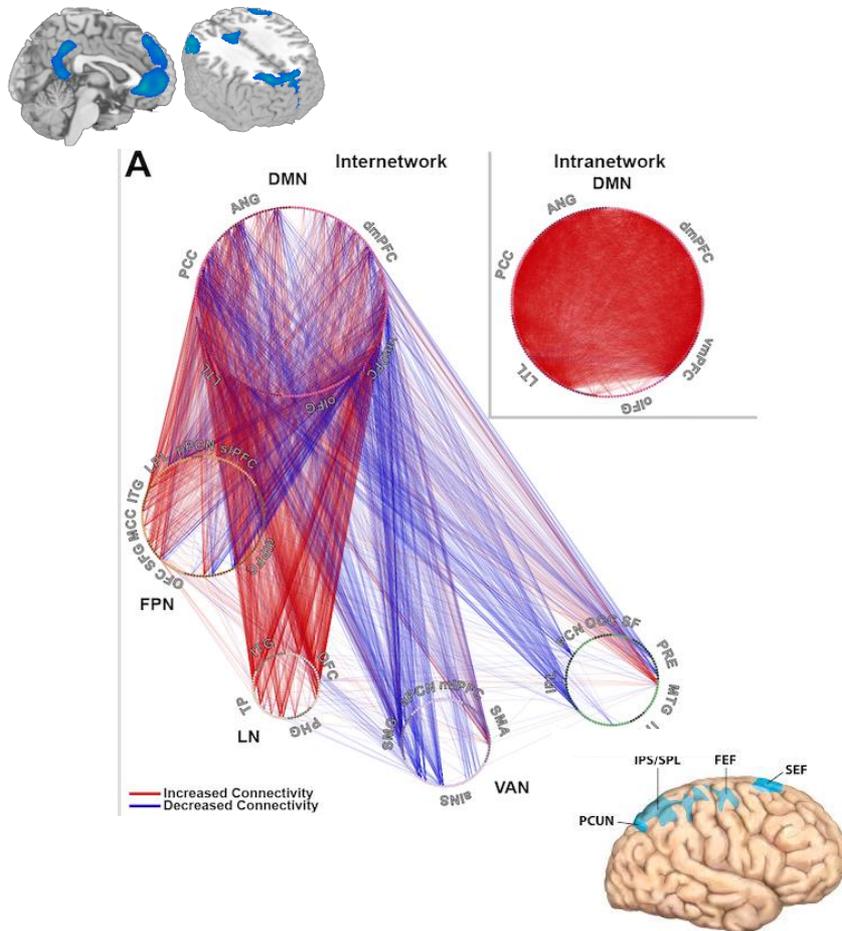


**Firing of Locus Coeruleus Neurons**

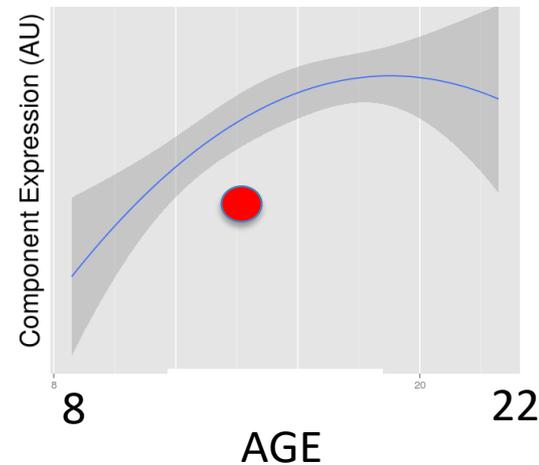


# Children Mind Wander Much More Than Adults

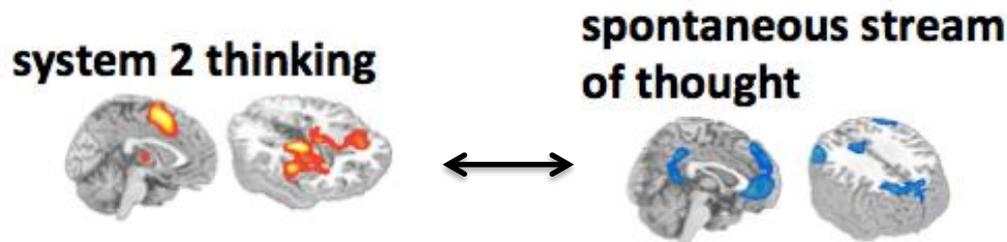
## Interconnections Between Default Mode Network and “System 2” Networks Predict the Decline of Mind Wandering From Childhood to Adulthood



### Brain Network Growth Chart



# The “Portfolio” model



The mind regulates the quantity of system 2 thinking and spontaneous thinking to achieve a balanced portfolio

The balance is achieved over multiple timescales

## **short timescales**

oscillations over minutes to hours

feelings of cognitive fatigue favor more mind wandering

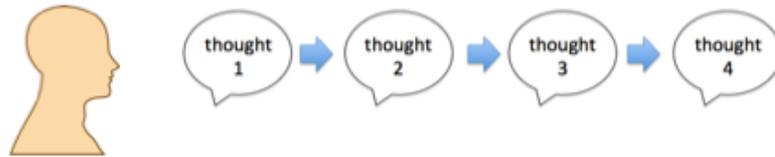
feelings of boredom favor more system 2 thinking

## **long timescales**

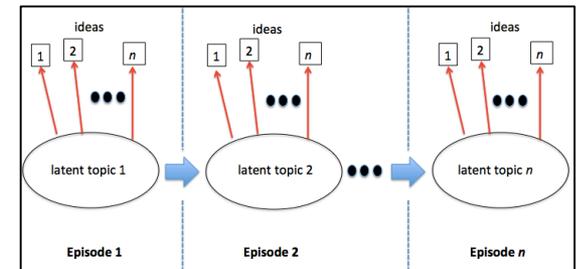
optimal balance changes over the lifespan

# Summing Up: Two Central Questions About the Spontaneous Stream of Thought

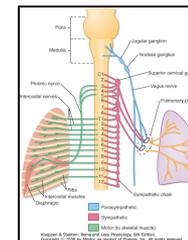
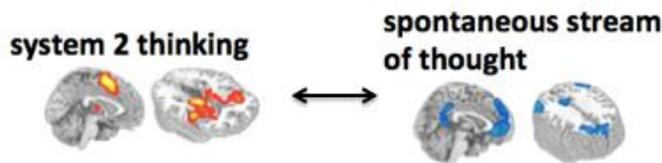
**1. Mechanism Question:** How do spontaneous thoughts get “stitched” together into a sequence?



## Topic Hopping Model



**2. Regulation Question:** How does the mind regulate switches between goal-directed system 2 thinking and spontaneous thinking?



Breathing Analogy  
Combines  
Automaticity and  
Control



Portfolio Model

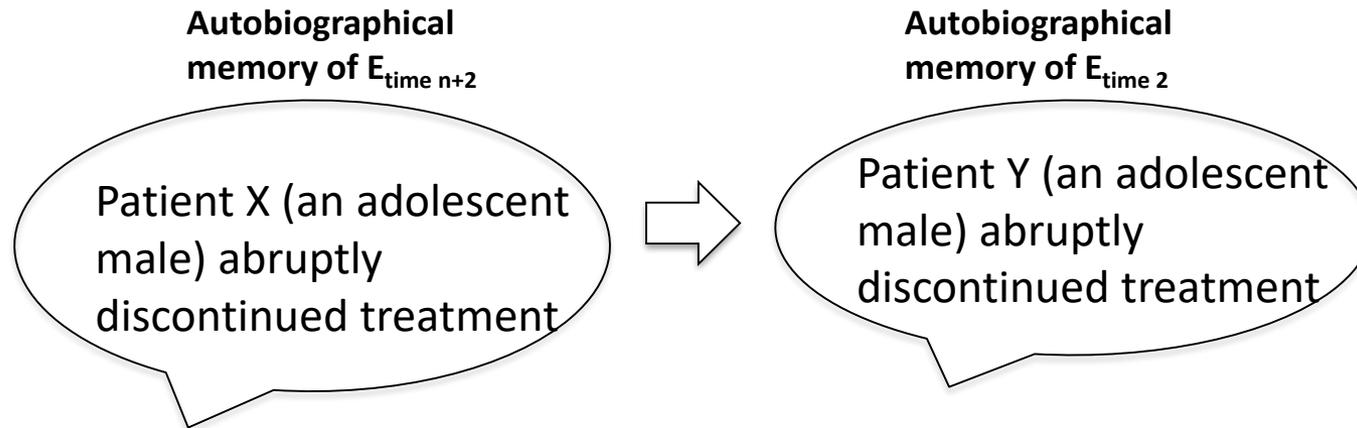
The End

## Why Producing Associative Streams Is Good for Pattern Discovery

Experience itself is always temporally ordered



When memories of experience are replayed in mind wandering, the constraint of temporal ordering is removed

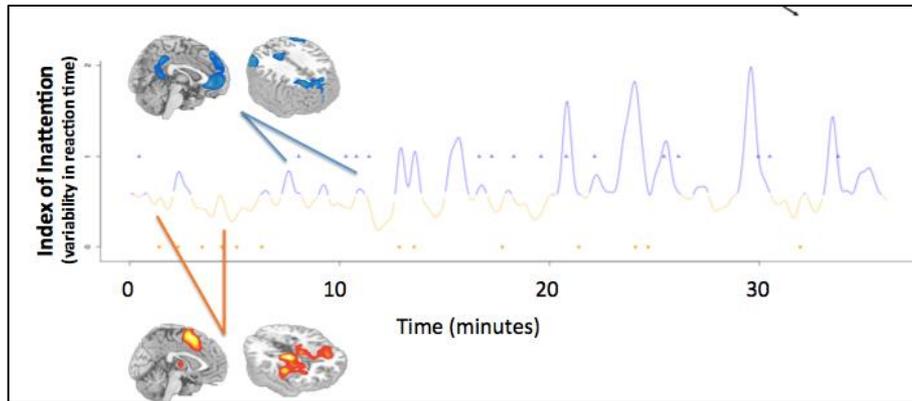


Where two ideas are already linked by one associative connection, there are likely to be others awaiting discovery.

Producing associative streams help you see relevant ideas “side-by-side” so you can uncover additional hidden associative connections between them!

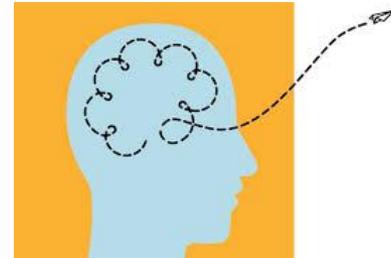
Why do we do so much mind wandering?

Why is there a quasi-periodic ongoing desire to mind wander?



Because mind wandering is an exploratory activity that facilitates pattern discovery.

# Future Directions: “Positive Mind Wandering”?



# “Negative Mind Wandering” is Thriving!

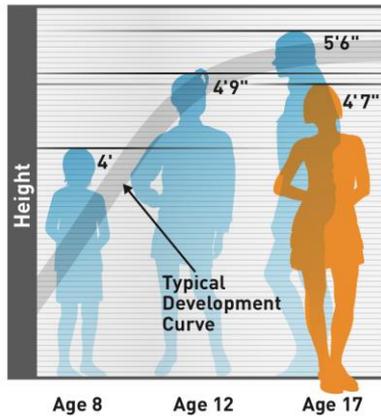
## ADHD

Problems in  
**Timing** of Mind  
Wandering

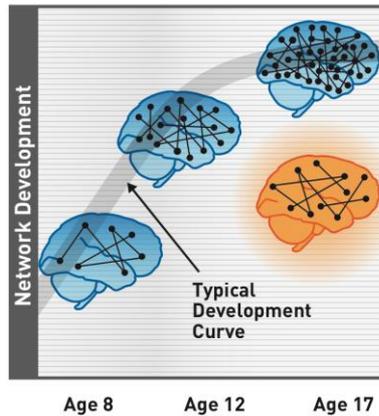
We created “growth charts” for default network and task-positive networks--the networks that underlie mind wandering

Children whose networks are “immature for age” display excess mind wandering during attention tasks

Growth Charting of Height



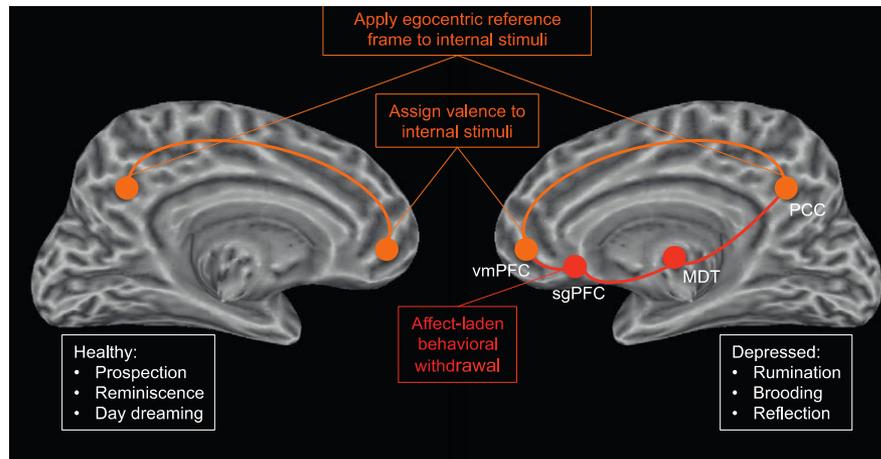
Growth Charting of Brain Networks



Kessler, Daniel, Michael Angstadt, and Chandra Sripada. 2016. “Brain Network Growth Charting and the Identification of Attention Impairment in Youth.” *JAMA Psychiatry*.

## Depression

Problems in  
**Content** of Mind  
Wandering



Hamilton, J. P., Farmer, M., Fogelman, P., & Gotlib, I. H. (2015). Depressive Rumination, the Default-Mode Network, and the Dark Matter of Clinical Neuroscience. *Biological Psychiatry*, 78(4), 224–230

# “Positive Mind Wandering” needs to be developed!

The challenge: Build on “negative mind wandering” research to in order to improve the timing and content of mind wandering.

The goal should be to measure and cultivate mind wandering that supports:

Insight

Imagination

Creativity

Openness to Ideas

Optimism

Resilience

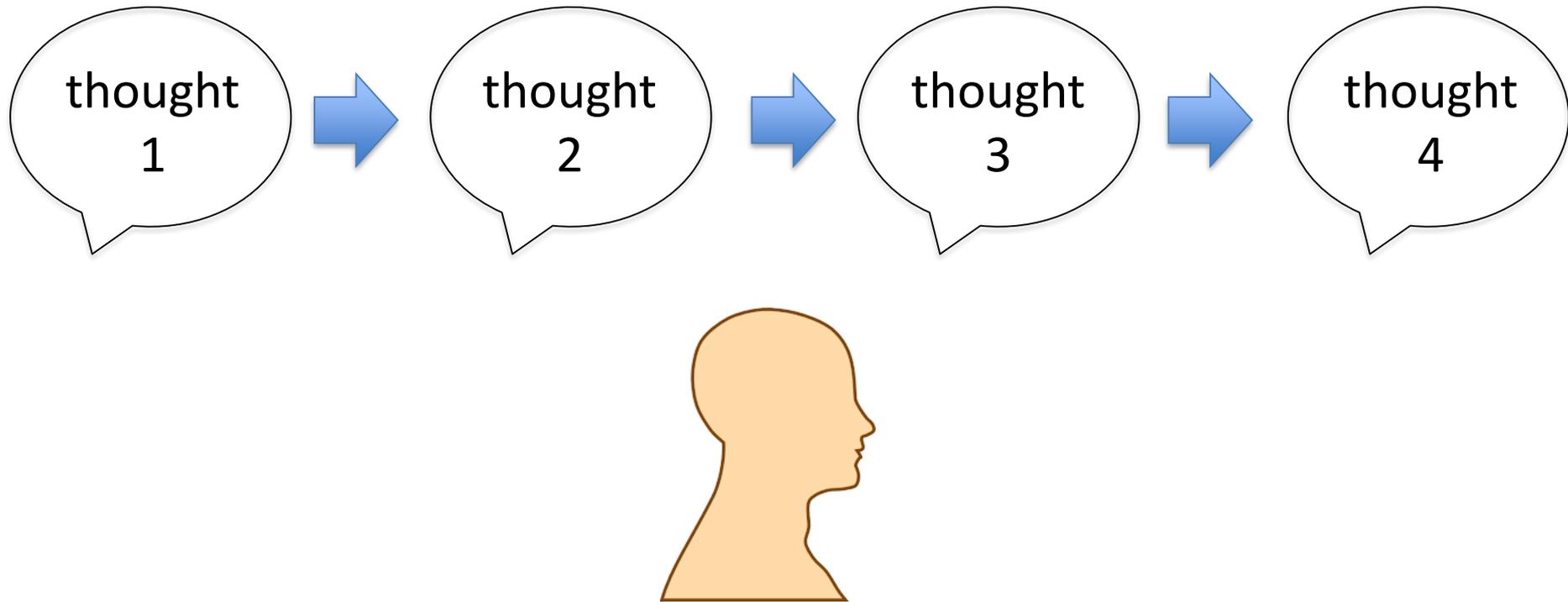
	A	B	C	D	E	F	G	H
1	<b>Subject</b>	<b>Thoughts</b>						
2	50	It sounds like the air conditioner in the lounge						
3	50	This shirt is really soft						
4	50	I can probably meditate to this white noise sound						
5	50	That's a really old phone, it looks ancient						
6	50	Well not that ancient						
7	50	The one in my house is worse						
8	50	I wonder how many people actually use that phone						
9	50	I wonder what the blue light on the ceiling thing is						
10	50	It might be a fire alarm I'm not totally sure						
11	50	I can't wait to get a cat next year						
12	50	I need to find a seventh roommate though						
13	50	And get lots of plants						
14	50	I like plants						
15	50	I think I might get some empty wine bottles and put plants in them						
16	50	And have a nice little rack in the living room with a bunch of plants in wine bottles						
17	50	If I put them in the plants or vines it'd be like spilled wine which is a beautiful						
18	50	Just staring at the ceiling right now						
19	50	I wonder if I can hang stuff on the ceiling						
20	50	The lounges ceilings are all messed up they're similar						
21	50	But you can't set the tiles back in easily						
22	50	People hang balloons on them						
23	50	I wonder if I can hang balloons on the ceiling in the house next year, that'd be fun						
24	50	Does my house have overhead lighting						
25	50	I can't remember						
26	50	Maybe I'll just do fairy lights or something if it doesn't, whatever works						
27	50	I can't wait to cook						
28	50	Just had chaparadda yesterday and it was so good, make more of that stuff						
29	50	I miss Chicago						
30	50	Mexican food is so good you can't get that here						
31	50	It's all gentrified, mediocre, and expensive crap						
32	50	Ugh I wanna make stuff						

	A	B	C	D	E	F	G	H	I	J	K	L
1	Subject	Index_AE	Index_SF	Index_SR	Index_Sum	Thoughts						
2	50	0	0	0	0	It sounds like the air conditioner in the lounge						
3	50	0	1	0	1	This shirt is really soft						
4	50	1	1	0	3	I can probably meditate to this white noise sound						
5	50	1	0	1	3	That's a really old phone, it looks ancient						
6	50	0	1	0	1	Well not that ancient						
7	50	0	0	0	0	The one in my house is worse						
8	50	1	1	1	3	I wonder how many people actually use that phone						
9	50	1	1	1	3	I wonder what the blue light on the ceiling thing is						
10	50	0	0	0	0	It might be a fire alarm I'm not totally sure						
11	50	1	0	1	2	I can't wait to get a cat next year						
12	50	1	0	1	2	I need to find a seventh roommate though						
13	50	1	1	1	3	And get lots of plants						
14	50	1	1	1	3	I like plants						
15	50	1	0	1	2	I think I might get some empty wine bottles and put plants in them						
16	50	1	1	1	3	And have a nice little rack in the living room with a bunch of plants in wine bottles						
17	50	0	0	0	0	If I put them in the plants or vines it'd be like spilled vine which is a beautiful						
18	50	0	0	0	0	Just staring at the ceiling right now						
19	50	0	0	1	1	I wonder if I can hang stuff on the ceiling						
20	50	1	1	1	3	The lounges ceilings are all messed up they're similar						
21	50	0	0	0	0	But you can't set the tiles back in easily						
22	50	0	0	0	0	People hang balloons on them						
23	50	0	0	0	0	I wonder if I can hang balloons on the ceiling in the house next year, that'd be fun						
24	50	0	1	0	1	Does my house have overhead lighting						
25	50	0	0	0	0	I can't remember						
26	50	0	0	1	1	Maybe I'll just do fairy lights or something if it doesn't, whatever works						
27	50	1	1	0	2	I can't wait to cook						
28	50	0	0	0	0	Just had chaparadda yesterday and it was so good, make more of that stuff						
29	50	1	1	1	3	I miss Chicago						
30	50	1	0	1	3	Mexican food is so good you can't get that here						
31	50	0	0	1	1	It's all gentrified, mediocre, and expensive crap						
32	50	1	0	0	1	Ugh, I wanna make stuff						
33	50	0	0	0	0	I miss making stuff from home, bakers feast						
34	50	0	0	0	0	Though I do have work on Friday at the baker's feast						
35	50	0	0	0	0	I could probably make stuff then						
36	50	0	0	0	0	I need to make the bean [unintelligible], making a t-shirt box holder						
37	50	0	0	0	0	I've been meaning to do that for a while						
38	50	0	0	0	0	I have to get [filament dough]						
39	50	0	0	1	3	, I guess I'll probably use some of that [playfilm]						



**Suppose you are sitting on a bus wide awake. It is dark.  
There isn't anyone near you.**

**Is your mind completely quiet?**



**spontaneous stream of thought = “mind wandering”**