Conceptual change for behavioral change

towards educational approaches to climate change and human motor function

JHU - Sept 27, 2012

Dav Clark

Where I’m from

The Struggle

- Cognitive science: really cool theories
- Applying these theories to help people is really hard
- Things like walking & balance seem tractable *and* change people's lives
- I got interested in such things via mind-body education

What I mean by "mind-body"

- Basic idea: you learn something, and your health improves
- A central problem:
  - Faulty conceptions are like visual neglect
  - You often *don't know* you *don't know*
- But, learning can work therapeutically, and be *cheap*, relatively *fast* and have *few side effects*!
  - My personal beliefs were radically violated in a 3 hour "Awareness through Movement" workshop

Theory & Practice make opposing demands

- For clean theoretical experiments, we prefer the simplest system possible
- Real-world education and therapy require real-world scale descriptions
- I'd like to help you build models for:
  - controlled experimentation
  - ready application

Overview

1. Why should a (body oriented) movement scientist care about e.g., climate change education?
2. Conceptual interventions for informed (world oriented) policies
3. Future work!

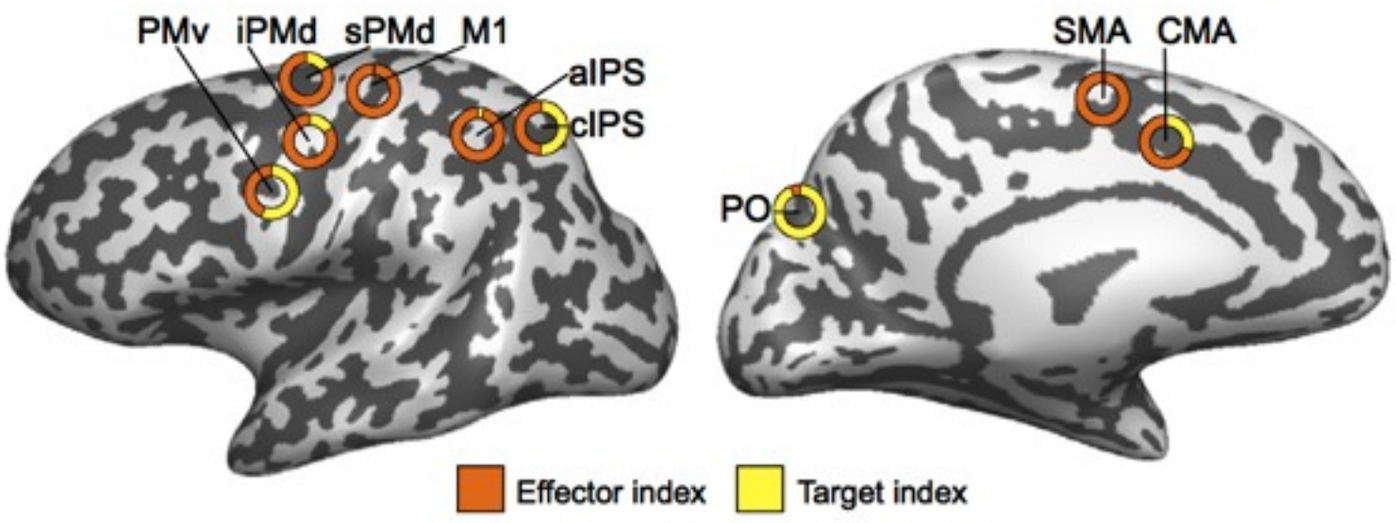
Overview

1. Why should a movement scientist care about policy-relevant education?
    - **Similar networks likely subserve complex motor *and* world-directed decisions & actions**
    - Central principles cut across these domains
2. Conceptual interventions for informed policies
3. Future work!

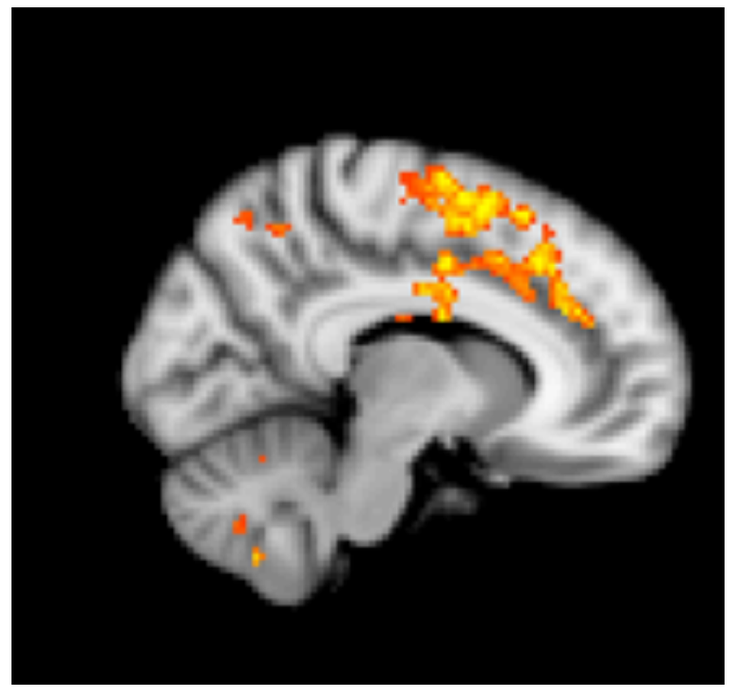
Overlap in the Brain: Decision & Action

- Much of the decision making literature is focused on selection between objects or goals in the world

- But recent work indicates marked overlap between motoric effector selection and goal selection in the world



Beurze, et al. (2009)



Stoloff, Clark & Ivry (in prep)

Overview

1. Why should a movement scientist care about climate change education?
    - Similar networks likely subserve complex motor *and* world-directed decisions & actions
    - **Central principles cut across these domains**
2. Conceptual interventions for informed policies
3. Future work!

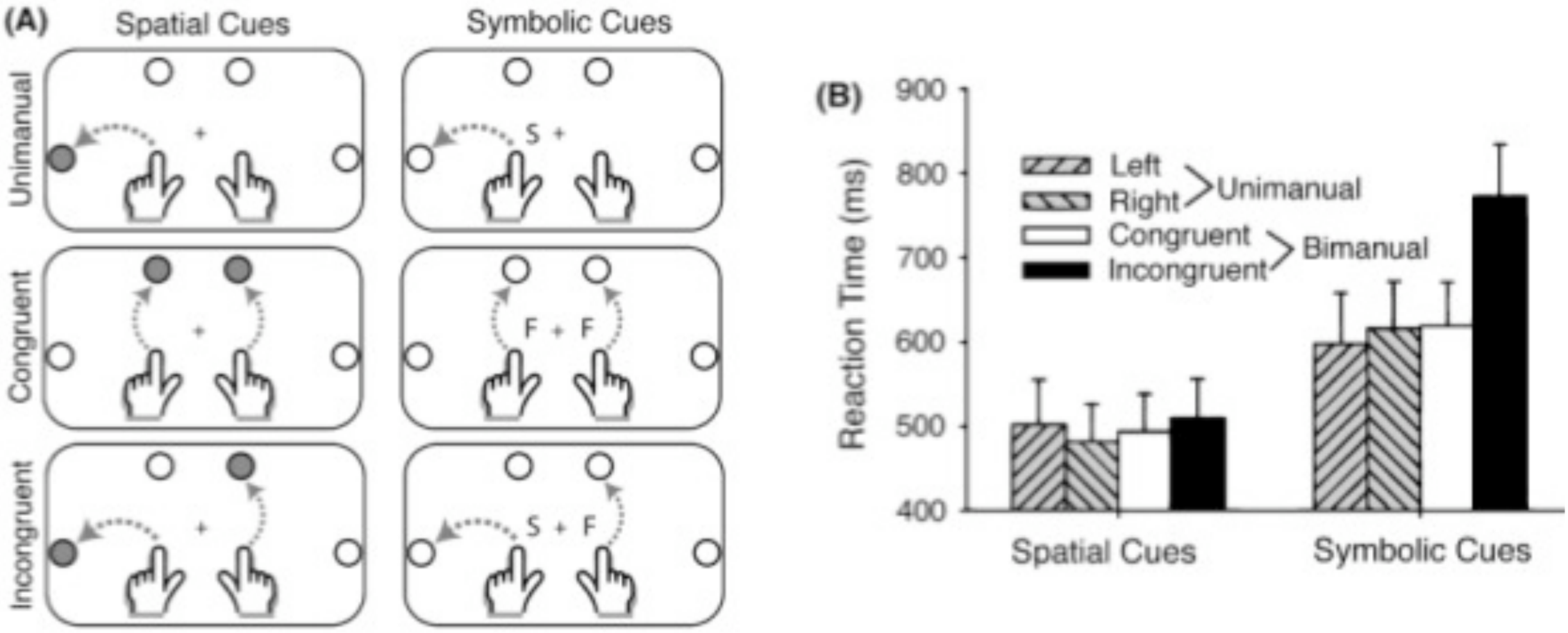
Thinking "Fast & Slow"

More conceptual	More encapsulated
Lots of learning (per experience)	Small, incremental learning
Requires extra time & resources, more serial	Automatic / effortless, more parallel
Accessible to awareness / intention	Impenetrable to awareness, independent of conscious strategy
Necessary for contextual learning	Narrow /preset focus of information
(Enhanced) consolidation during sleep	Consolidates with passage of time
Easier transfer to related tasks	Task-specific & inflexible
"Rational" and recollective	Emotional and intuitive

Sources / Touchstones

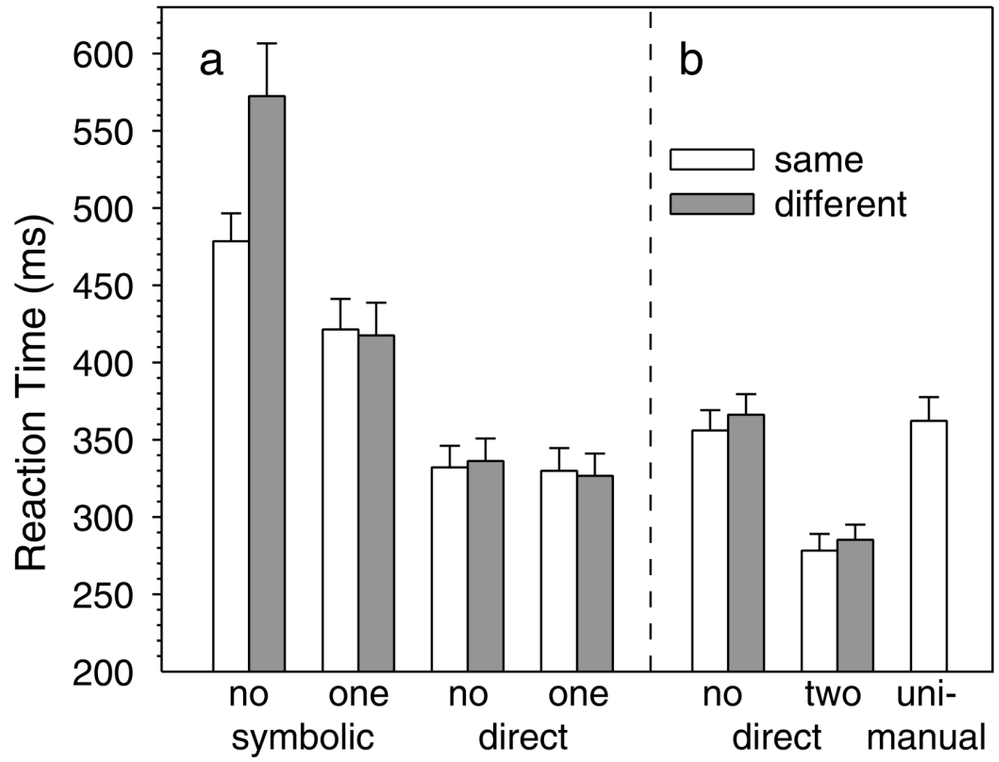
- Modified from Clark & Ivry (2010)
- Moshe Feldenkrais (1949)
- Behavioral Economics / Change – Kahneman (e.g., Attention and Effort, 1973)
- Development / Cognitive Architecture – Sue Carey and colleagues (e.g., 2011)
- Serial Reaction Time – Keele, Ivry, Mayr, Hazeltine & Heuer (2003): Uni- vs. multi-dimensional
- Visuo-motor rotation – Smith & Shadmehr (2006)

Example of "conceptually guided" reading



Cost of concept is additive with spatial mapping

- A similar pattern occurs in first-person space, but reaction times are faster overall



- Thus, there appear to be two S-R costs:
  - Spatial transformation: ~150 msec, no "leakage," likely wrecks "mirror box effect"
  - Symbolic cueing: ~100+ msec *and* "leakage"

Commonalities between "world" and "body"

- Action selection involves similar brain regions for goal selection in the *world*, and effector selection in the *body*
  - Hence, similar processes?
- Motor execution & learning exhibits both "conceptual" and "encapsulated" processing and learning
  - Just as seen in other forms of cognition

Overview

1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for informed policies
   - **Learning for policy-relevant numerical estimation progresses via multiple routes**
   - Beliefs and attitudes about climate change are only partially related to actual knowledge
3. Future work!

The *Numerically Driven Inferencing* (NDI) Paradigm

- How can we help people make well-reasoned, evidentially-based decisions / policies?
- Ranney's Reasoning Group introduced NDI paradigm in 2001, engaging folks with critical, germane and credible base rates:
  - Enduring improvements in estimation, and
  - shifts in policy / preferences (real-world impact)
  - for groups ranging from journalism grad students to grade schoolers
- As with many things, it's easier to explain using an example

ESTIMATE

What is the annual number of abortions per 1,000,000 live births in the U.S.A.?

[__ abortions
per 1,000,000 live births]

PREFERENCE?

What is the annual number of abortions per 1,000,000 live births in the U.S.A.?

[__ abortions
per 1,000,000 live births]

Ready to be INFORMed?

What is the annual number of abortions per 1,000,000 live births in the U.S.A.?

[X abortions per 1,000,000 live births]

Any CHANGE in preference?

What is the annual number of abortions per 1,000,000 live births in the U.S.A.?

[274,000 abortions per 1,000,000 live births]

The EPIC Procedure

- Estimate
- Preference
- Inform / Incorporate
- Change preference

- One of the cornerstones of the NDI paradigm

Conceptual Change, NDI style

- Munnich, Ranney and Bachman (2005) demonstrated persistent learning for up to twelve weeks with the EPIC procedure
- This is a minimalist intervention, ~5 minutes!
- Numerical estimates provide a point of contact with individuals' existing conceptual networks
- What happens to make this learning so successful?

Memory systems & Conceptual Change

A classic model: many episodic memories lead to abstract semantic memories

Alternative routes to updating existing knowledge?

- Amnesiacs and semantic knowledge?
  - Recall, amnesia = no new episodes
  - "Sometimes people hide pins in their hands" (Claparede, 1911)
  - Controlled experimental support in the animal literature Tse, et al. (2007)
- Might learning from surprising numbers also occur (sometimes) without episodic support?

Characterizing Learning for Improved Numerical Estimates

- We shift to a simpler, more controlled approach to allow for cognitive analysis
- Preferences / real-world impacts eliminated
  - EPIC → EI
- Do we observe evidence of encapsulated and/or conceptual learning for numerical estimates?
  - Conceptual: "consciously accessible" or "declarable"
  - Encapsulated: driven by emotion, e.g., "surprise"

ESTIMATE

What is the annual number of abortions per 1,000,000 live births in the U.S.A.? [__ abortions per 1,000 live births]

<>

ESTIMATE

What is the annual number of abortions per 1,000,000 live births in the U.S.A.? [__ abortions per 1,000 live births]

274,000

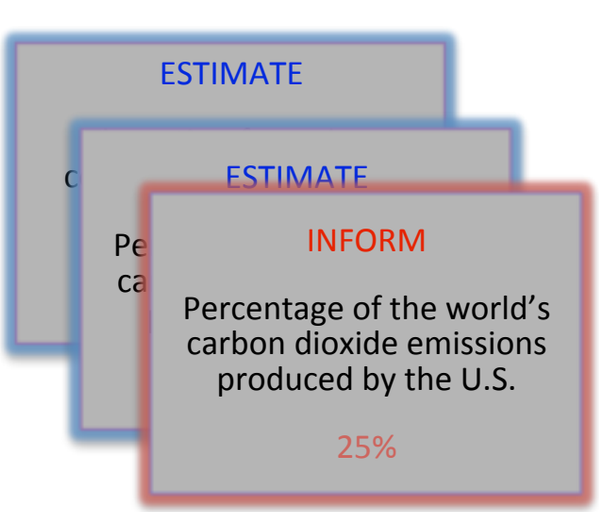
5,000

Learning - Day 1

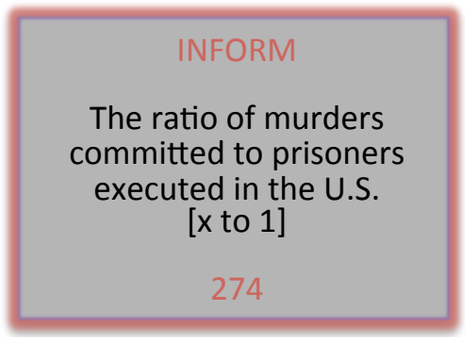
Estimate & Inform

Phase 1:
Estimate

Phase 2:
Immediate or Delayed Feedback



. . .



Day 1: 46 items w/ Feedback (+23 more w/o)

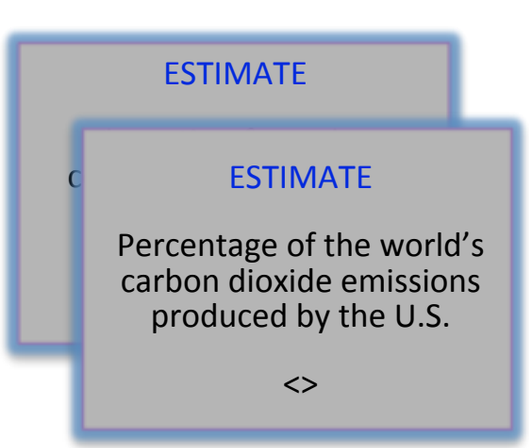
Surprise

- After feedback, subjects asked to rate their surprise:
  - 1 = None
  - 2 = Some
  - 3 = Visceral
- May reflect
  - Pre-existing knowledge
  - Affective strength of the item

Testing – Day 2

Estimate & Inform

Phase 1:
Estimate Only



Day 1: 46 items w/ Feedback (+23 more w/o)
Day 2: Old + 34 New items

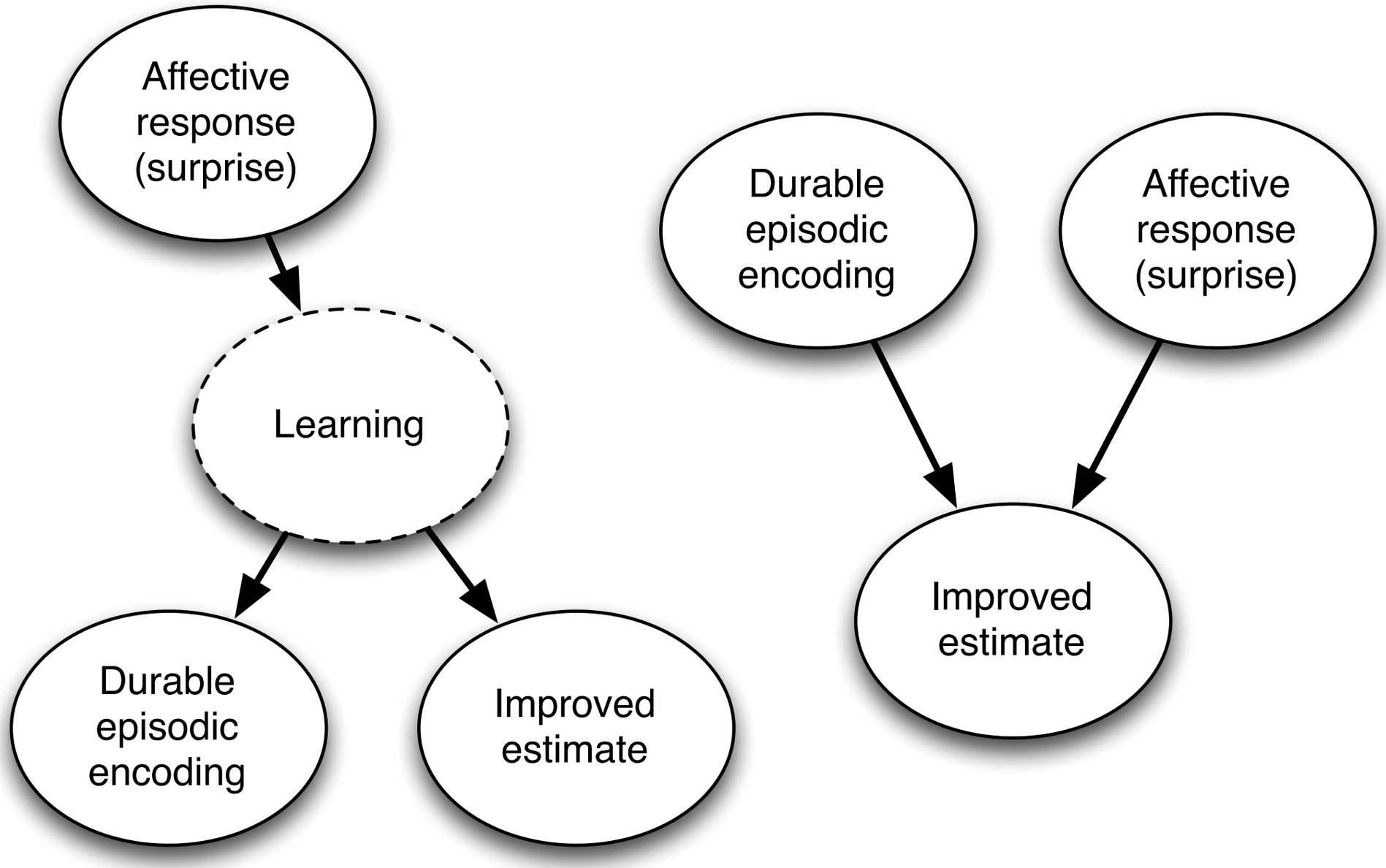
Metacognitive Assessment of Episodicity

- After the second estimation, participants metacognitively evaluated memory from day 1
  - 1 = New
  - 2 = Only description
  - 3 = Some idea of correct value
  - 4 = Exact recollection of correct value
- Memory assessment reliably indicates specific neural processes in learning and performance
- cf. “Feeling of Knowing” (Remember / Know; Familiarity vs. Recognition; etc.)

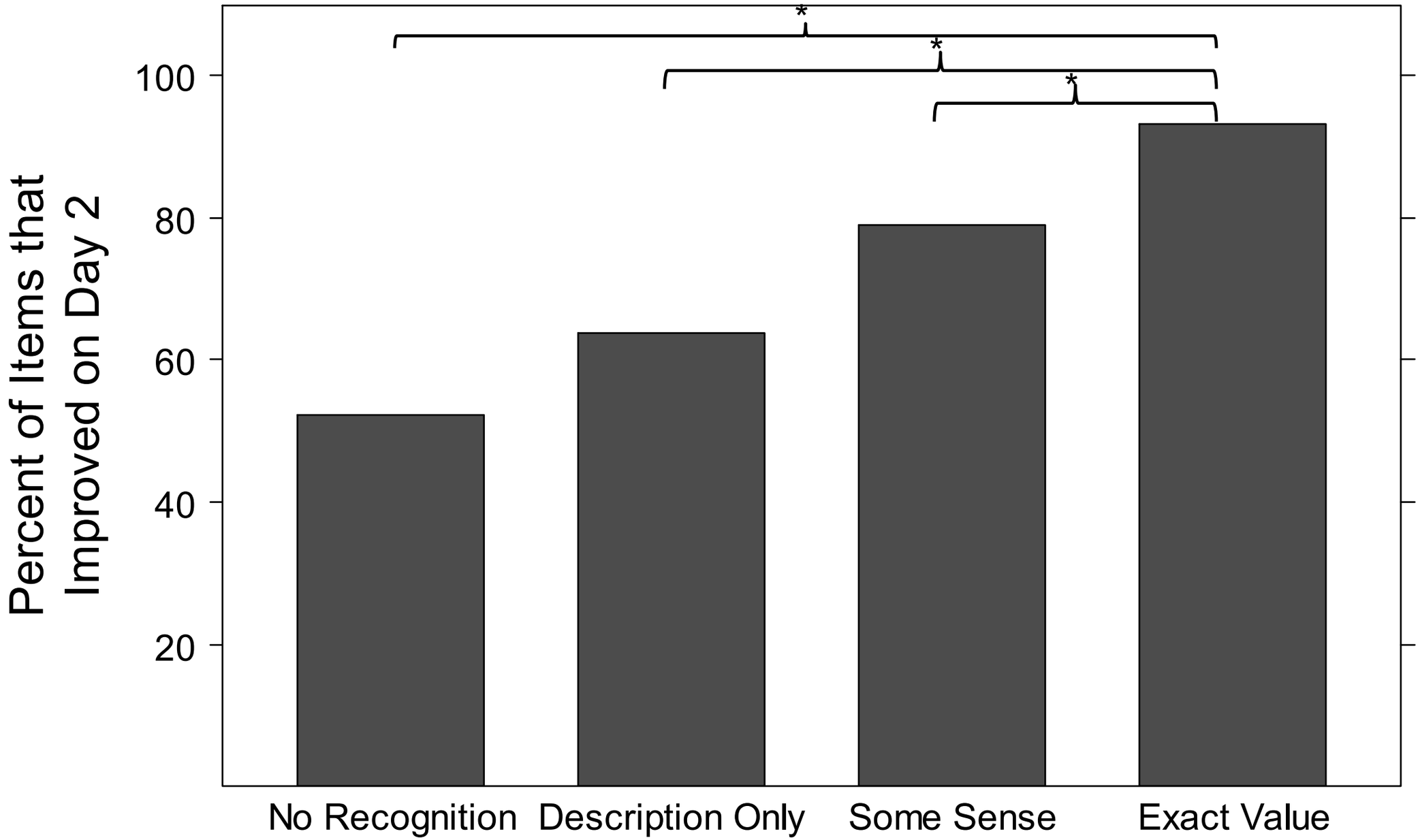
Central Questions

- Will we find evidence for learning that is relatively independent of episodic memory?
  - –The "standard model" would predict any change in semantic memory would happen via episodic memory
- Specifically, do surprise and metacognition (feeling of knowing) on episodic memory measure different underlying processes?

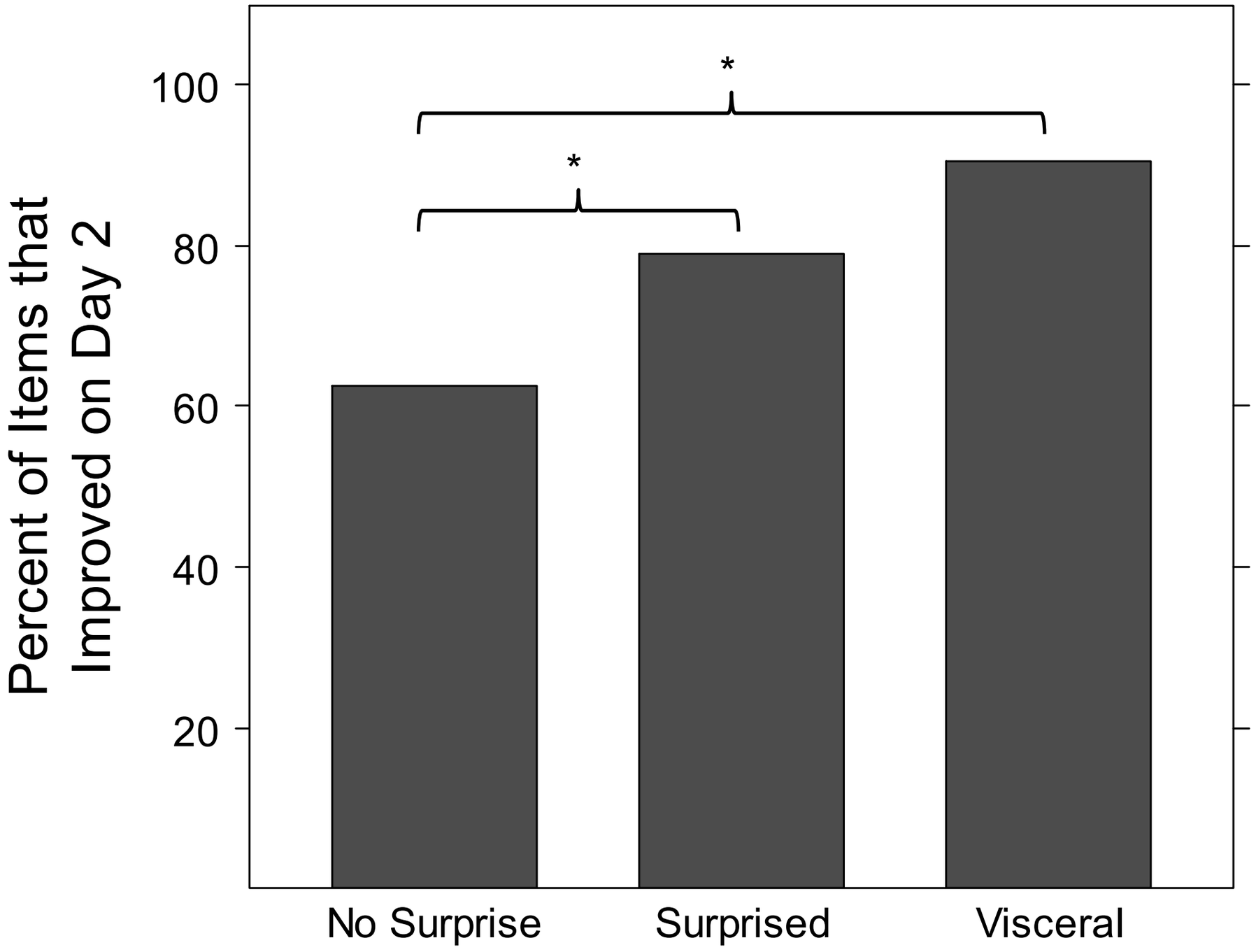
Hypotheses Graphically



Metacognition predicts improved estimation



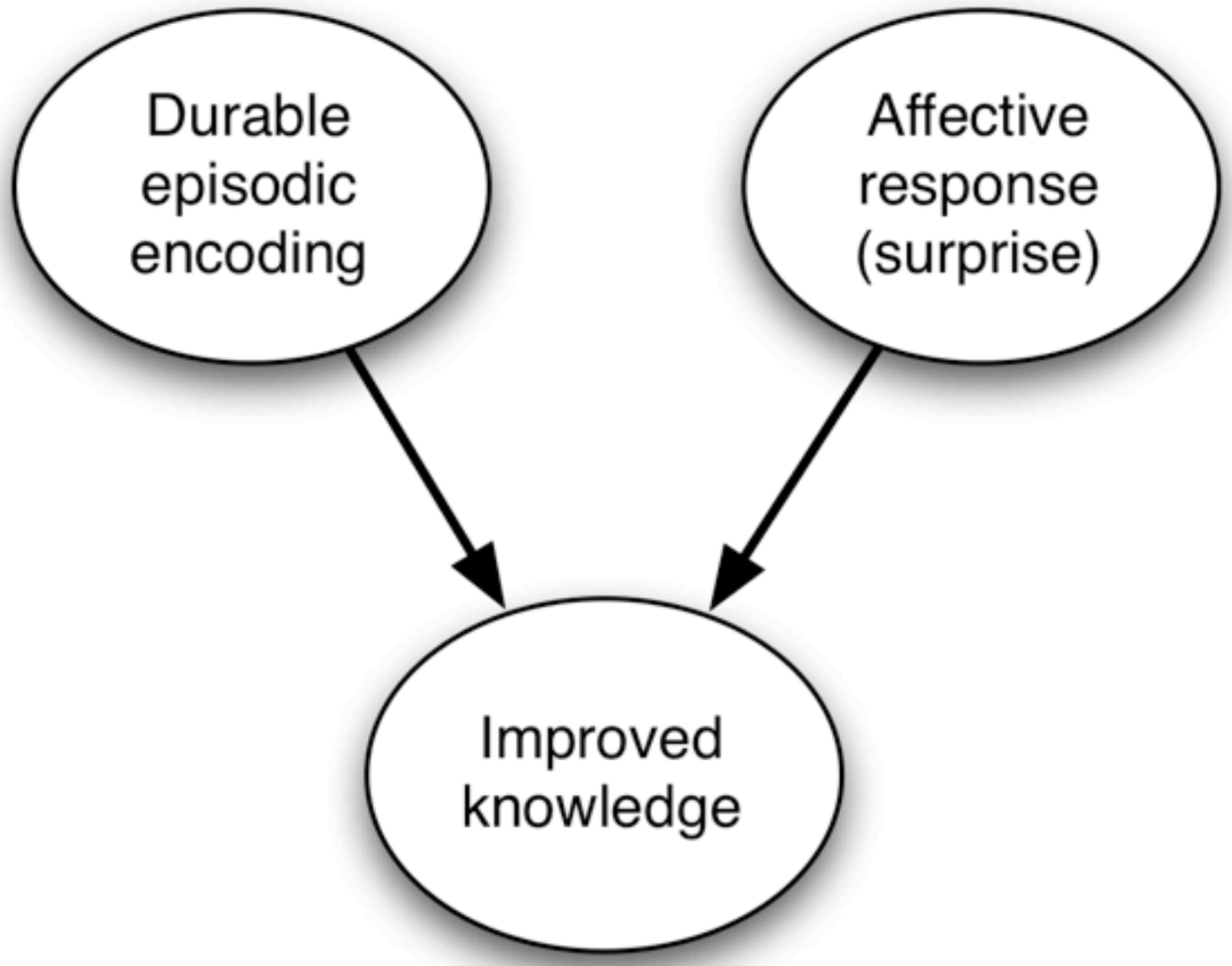
Surprise predicts improved estimation



Relationships between measures

- Metacognition is not so good:
  - Exact numerical figure given 35% of the time with "exact recollection"
  - Estimate within ±15% given about 74% of the time
- No interaction between surprise and episodic metacognition
- In addition, surprise and episodic metacognition are independent
  - Both Pearson and polychoric correlations are close to 0

Statistical independence!



Open Questions

- Can we actively manipulate what students know vs. what they think they know?
- Does the route change the accuracy / degree / stability of learning?
- What is most important in determining attitudes on controversial topics?

Overview

1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for informed policies
   - Learning for policy-relevant numerical estimation progresses via multiple routes
   - **Beliefs and attitudes about climate change are only partially related to actual knowledge (part 1)**
3. Future work!

Beliefs and Attitudes part 1

- First, we need to figure out the science for ourselves

- Then see:
  - What people know
  - What predicts beliefs and attitudes

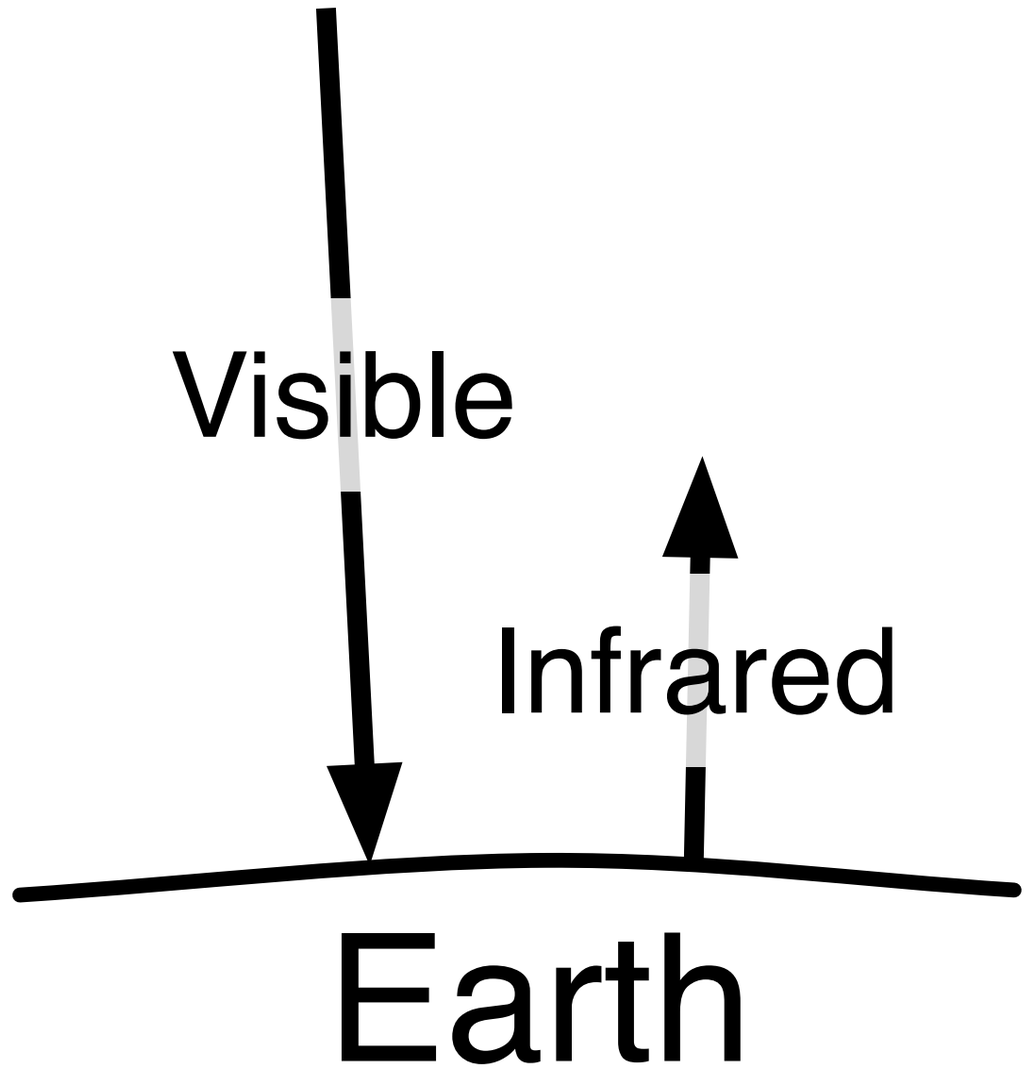
How is it that Earth is getting hotter?

- How would you explain how climate change occurs?
- Why does heat have a hard time getting away from Earth's surface and troposphere?
  - Shouldn't heat have just as hard a time getting in?
  - How do atmospheric molecules know "up" vs. "down"?
- Are all gases "greenhouse gases" (GHGs)?
  - If not, what makes something a greenhouse gas?
  - Is O_2 a greenhouse gas? Is N_2? Is CH_4?

Conceptual Change: Different Kinds of Light

- The sun's energy that gets to Earth's surface is mostly *visible* light

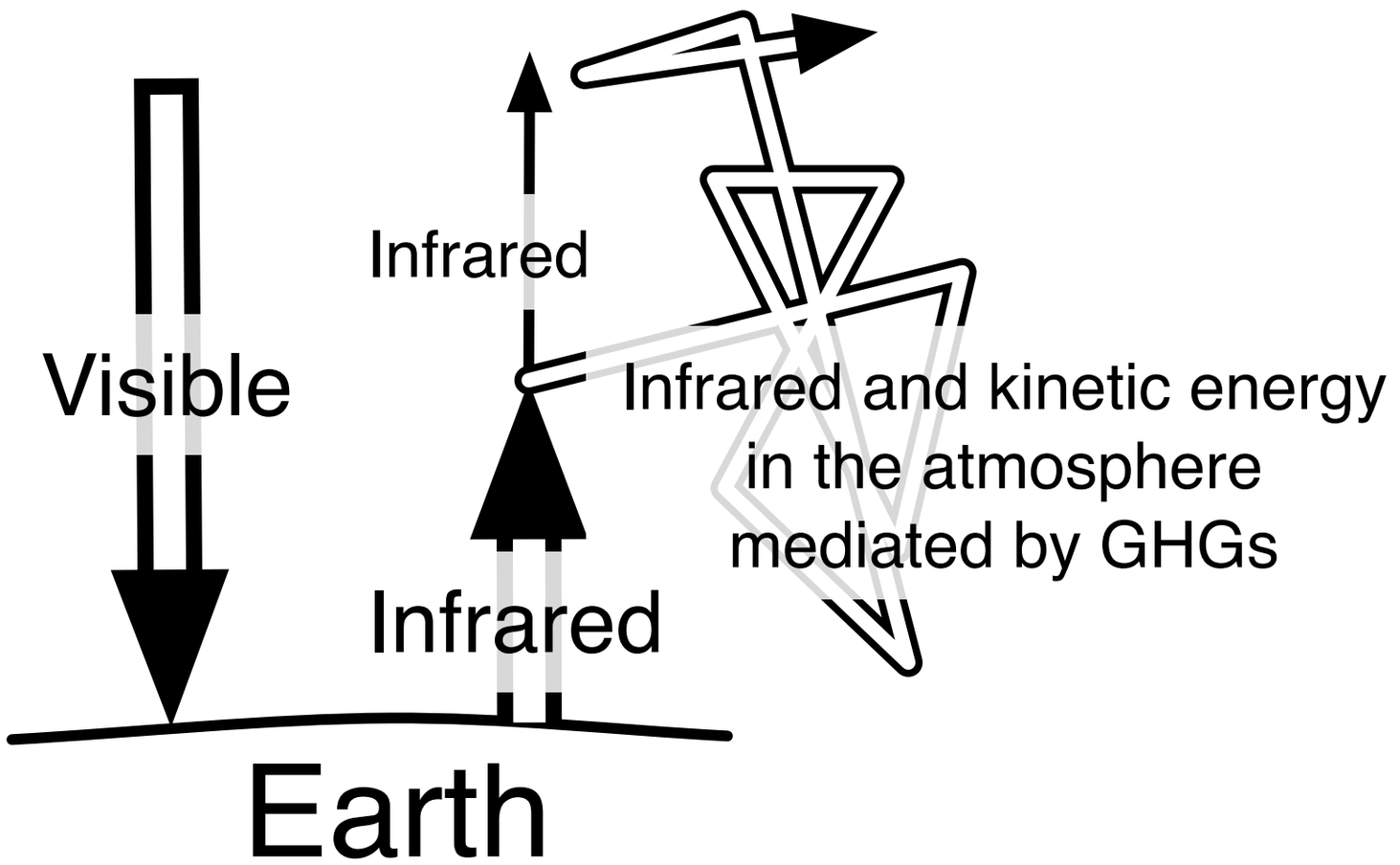
- It's absorbed and radiated later as *infrared* light



Conceptual Change: Not all Gases GHGs

GHGs:

- Readily absorb infrared photons
- Thus keeping that energy close to Earth's surface
- Such that only 10% of infrared photons go directly into outer space



Even you probably didn't know the mechanism…

- Surprise to us: huge lack of mechanistic understanding of climate change via GHGs
- Informally polled colleagues largely confessed ignorance or showed misconceptions
- Includes folks who are:
  - Well educated (e.g., college professors)
  - Fully accept global climate change as anthropogenic
- Akin to accepting evolution without understanding procreation
- Might this lack weaken political or personal resolve?

An Expert Opinion…

"No, it's not 'alright' that I didn't know! You don't understand: I've published papers about global warming!"

— A rather famous colleague

Surveying the public's climate beliefs in San Diego [Sarah Cohen]

- Shifting closer to a practitioner / educator approach
- Survey public knowledge and attitudes using both likert and semi-structured textual responses
    - Mechanistic knowledge, (Anthropogenic) climate change acceptance and other demographics
- Dealing with open-ended text (gold standard):
    - Develop codes for recurring themes
    - Independent coders assign these codes to each text
    - Check inter-rater reliability and (maybe) repeat!

275 San Diegans' (Mis)conceptions

- Rampant misconceptions about mechanism and causes
- Only 3% named the greenhouse effect
- When asked the "mechanism" questions:
  - 12% referred to emissions/pollution/CO_2 trapping heat
  - 0 / 275 were largely correct re: the effect, or mentioned the visible → infrared change
- Even though:
  - 70% agreed that "Human activities are a significant cause of global warming."

Attitudes seem to cluster

- Ranney (2012) notes relations between American beliefs and attitudes within a historical framework
- Many (e.g., Lakoff) predict that party affiliation should most strongly predict climate change acceptance
- As expected from Ranney's framework, *evolution acceptance* is a significantly better predictor of climate beliefs and attitudes than political party
    - For San Diegans, at least, but we suspect that will generalize...
- In any case, there's likely more than just conceptual knowledge driving attitudes and beliefs

Does Science (Mechanism) Education seem important?

- Above I suggested lack of knowledge might impact policy and personal action...
- For our San Diegans:
  - (Scored) Mechanistic knowledge correlated with acceptance of global warming as real and anthropogenic
  - Anthropogenic climate change acceptance significantly predicted all "willingness to sacrifice" items
  - Knowledge score significantly predicted two "willingness to sacrifice" items

Both conceptual knowledge *and* less rational processes give rise to attitudes

- Climate change mechanism knowledge predicts climate beliefs and attitudes
- But a cluster of other beliefs and attitudes also have an influence
  - For example, evolution has little bearing on whether climate change is real!
- Critically, global warming mechanism knowledge predicts both *belief* and willingness to *act*

Overview

1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for informed policies
   - Learning for policy-relevant numerical estimation progresses via multiple routes
   - **Beliefs and attitudes about climate change are only partially related to actual knowledge (part 2)**
3. Future work!

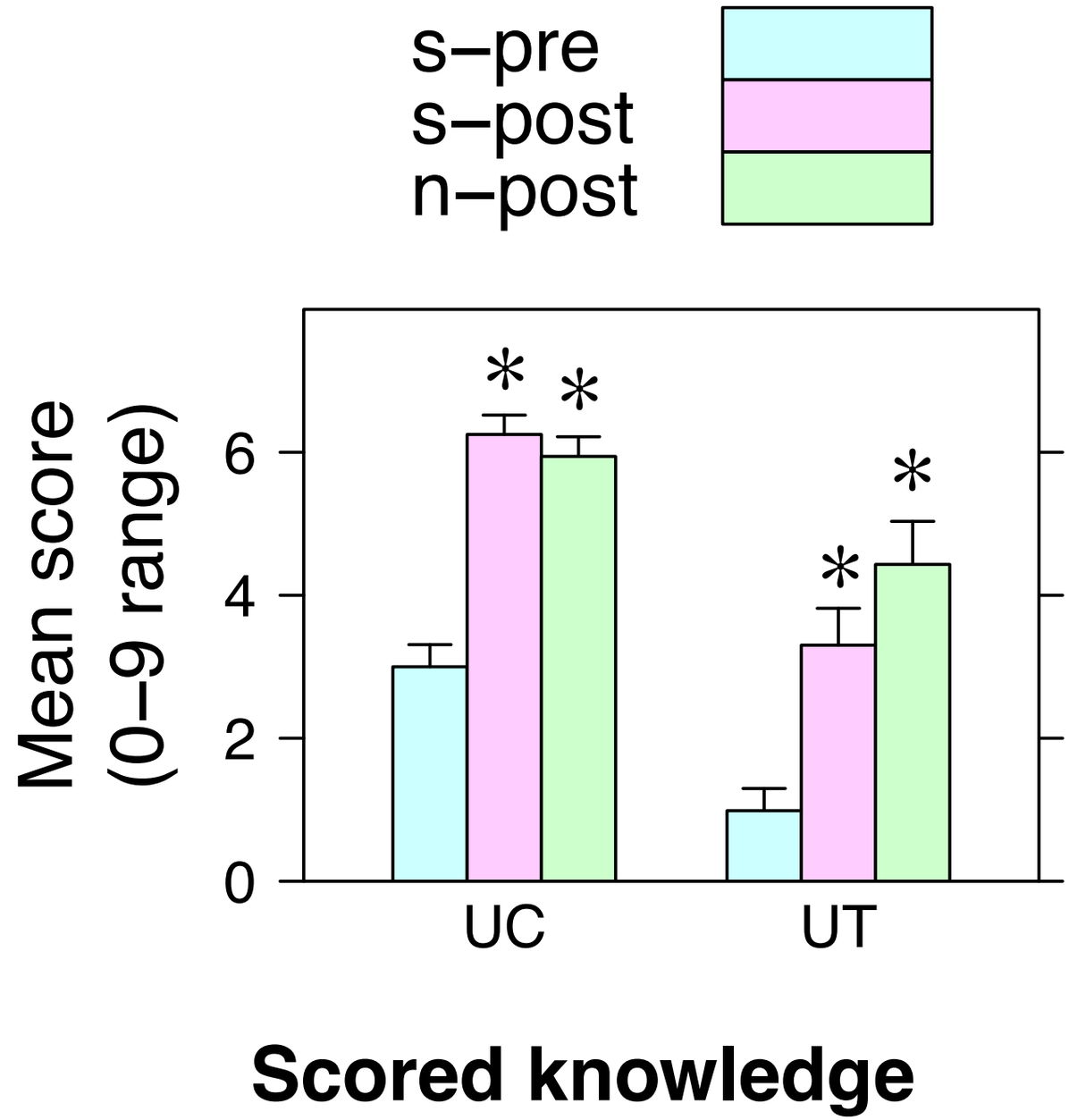
Beliefs and Attitudes part 2

- We now experimentally manipulate knowledge via an educational intervention
- We continue to assess knowledge and attitudes as in the above survey
  - Notably, our coding scheme was more developed (weighted $\kappa = 0.71$)

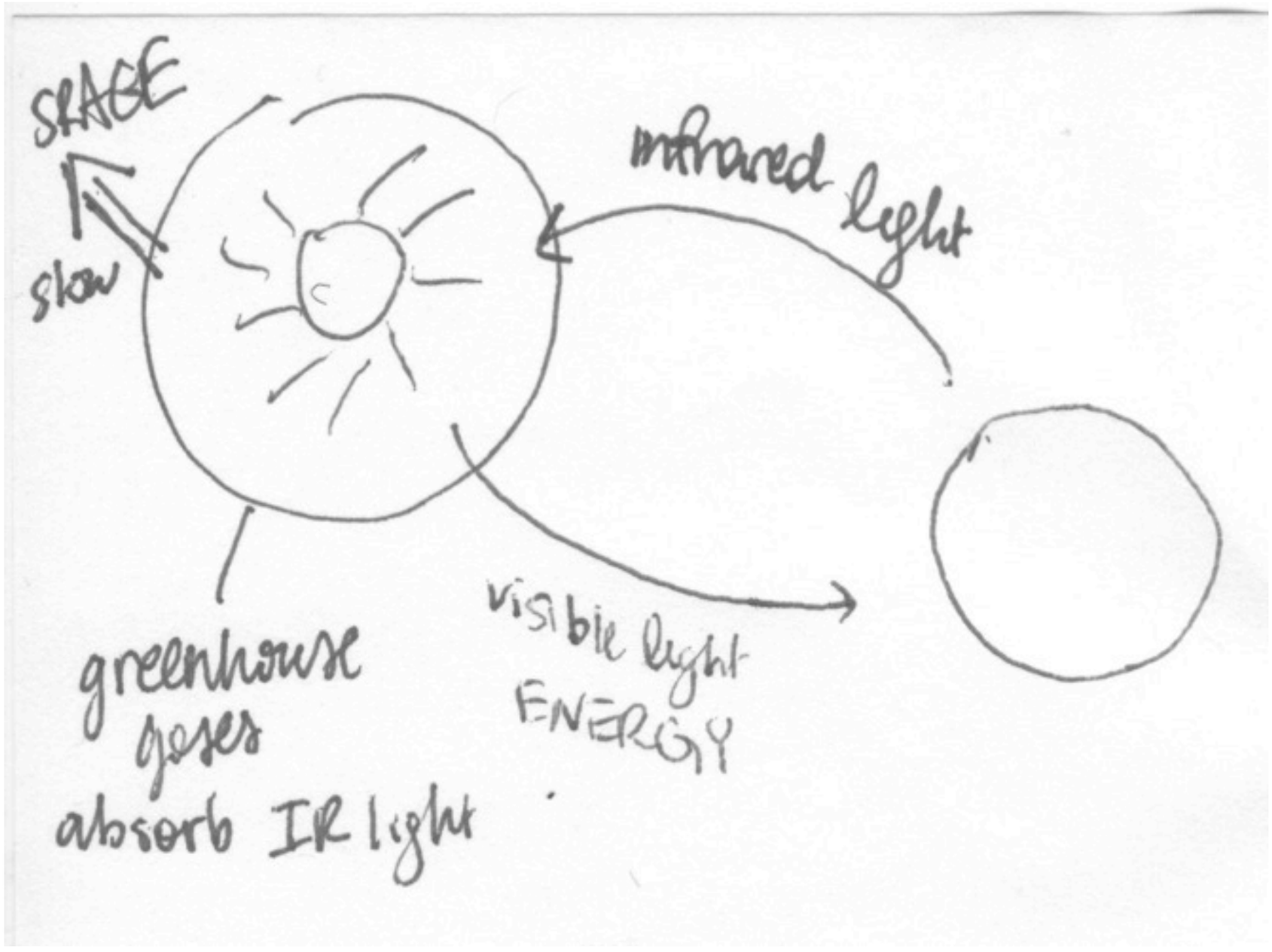
Mechanism Experiment

- Below, our tests are slices of bread
- And the 400-word educational intervention is the "jam"
- "Sandwich" (S) group:
  - (pre-test) Knowledge and attitude (9-point scales)
  - 400-word Description
  - (post-test) Knowledge and attitude
- "No pre-test" (N) group:
  - 400-word Description
  - (post-test) Knowledge and attitude

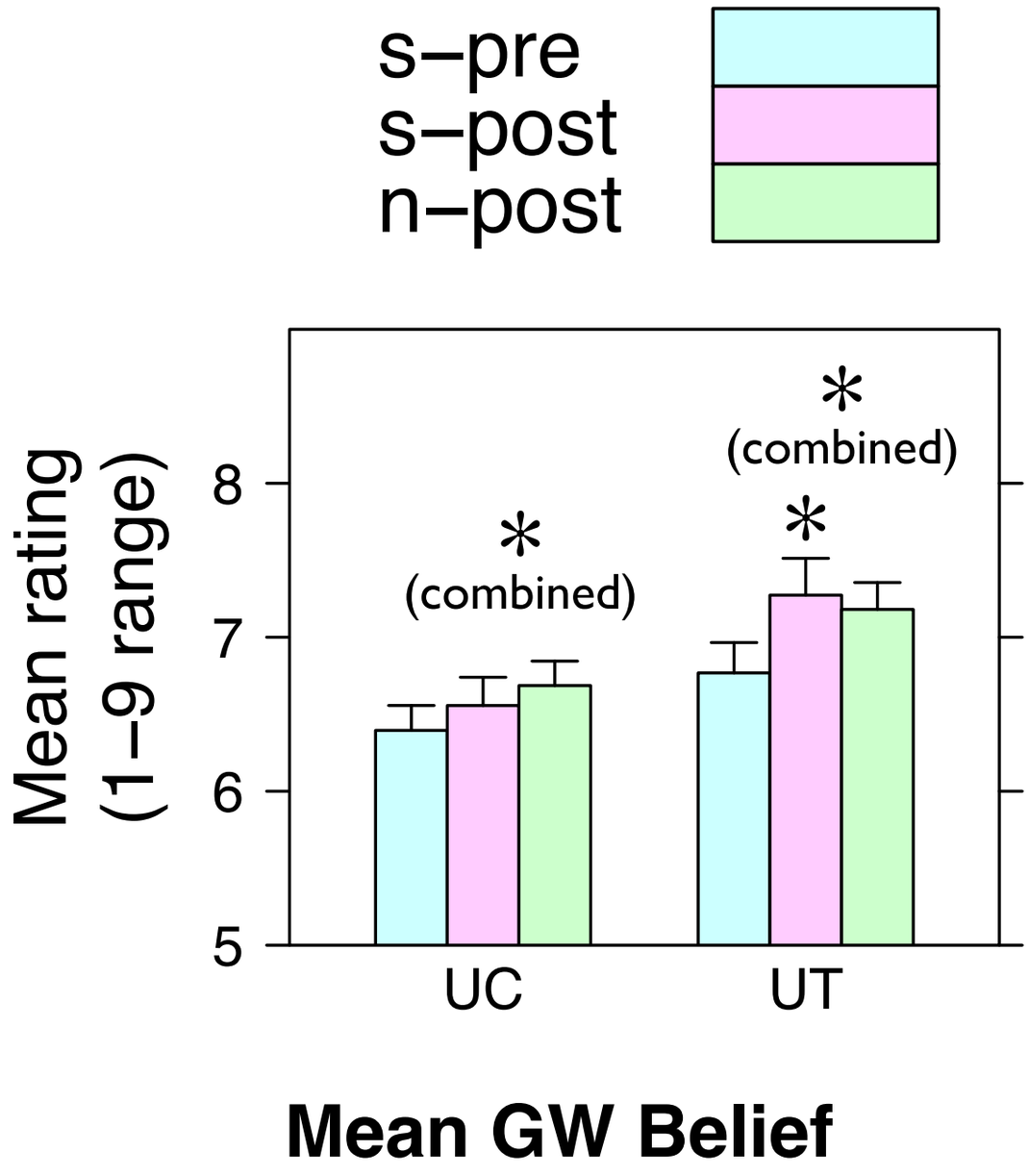
Marked changes in *real* knowledge



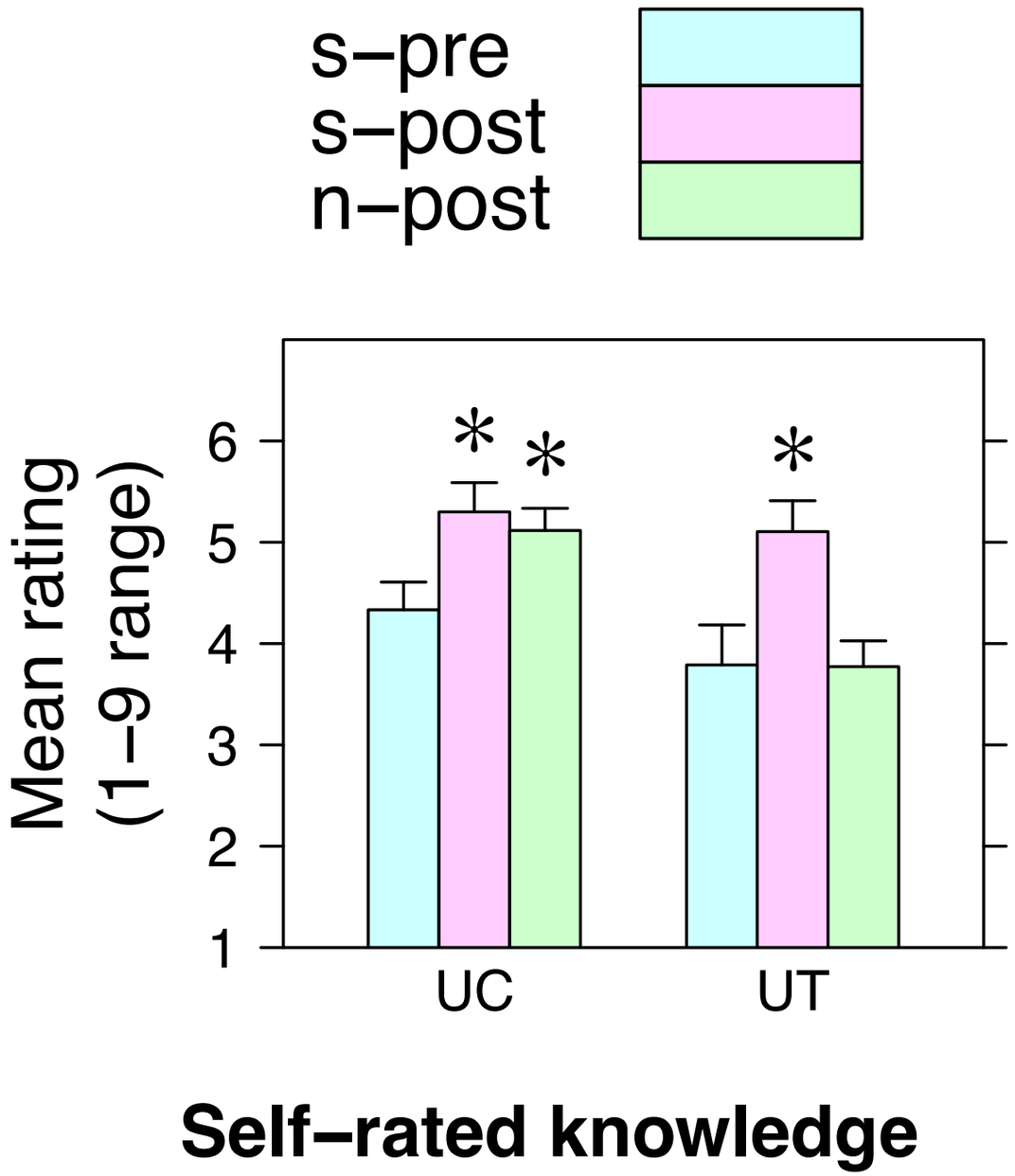
Some people end up with partial understandings



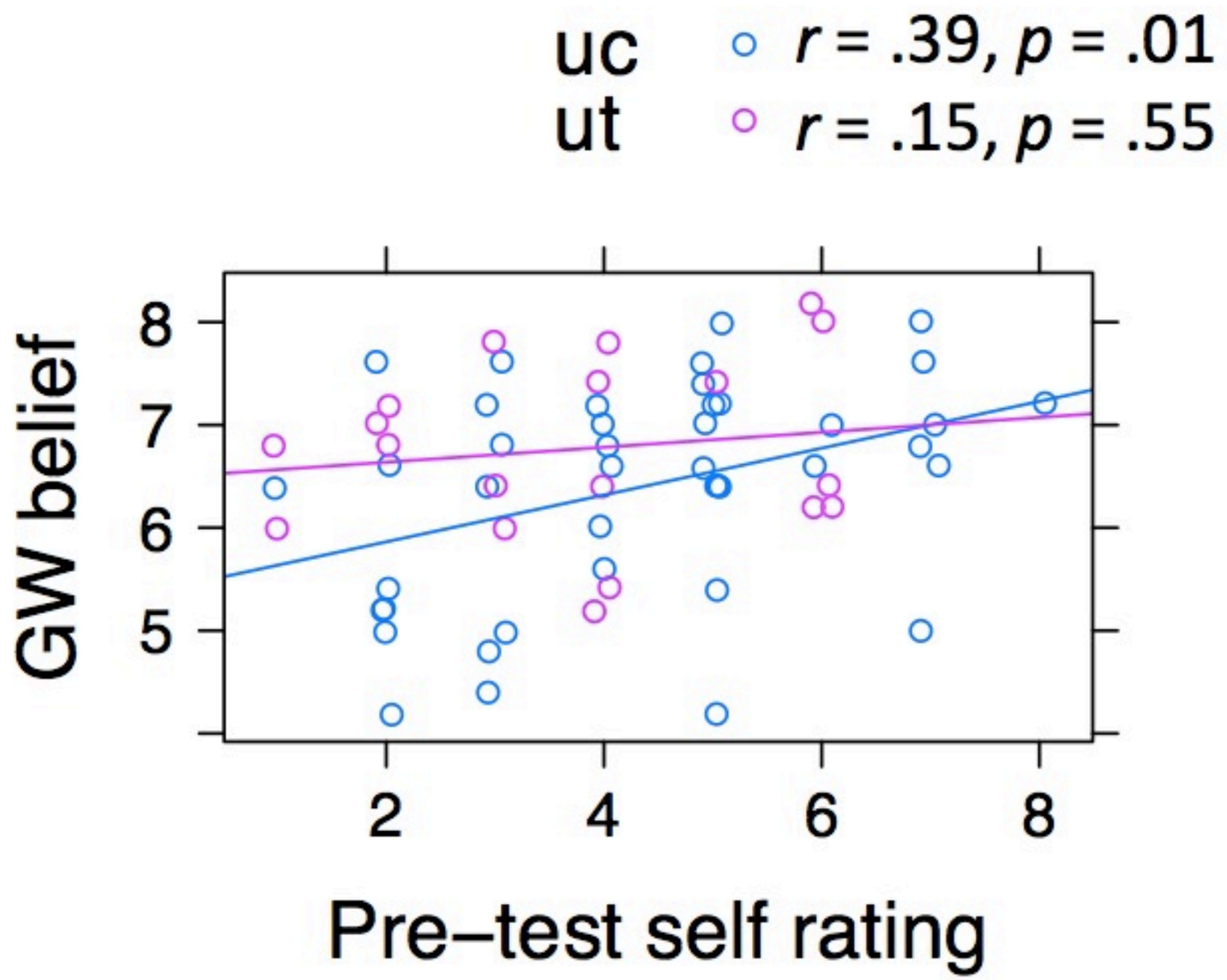
Significant changes in beliefs



Notable changes in self-rated knowledge



Differences in self-assessment between groups



Knowledge, Beliefs, & Attitudes shift together

- But individuals may require grounding (e.g., with self-assessment)
- Notably, self-assessment (sometimes) significantly predicts attitudes
  - An effect we didn't find with scored knowledge
  - But note, scored knowledge *did* predict attitudes in our San Diego survey
- Individuals appear to have an unexamined, easily filled gap in basic science understanding for climate change
  - Contrast with prevalence of strong opinions!

Open questions

- How do we identify when folks have well-calibrated self-assessment?
- What about emotional engagement?
  - While we did manipulate surprise, it didn't have significant predictive effects.
- We are currently:
  - Running a number of studies using (more) surprising numerical information
  - Broadening our target population

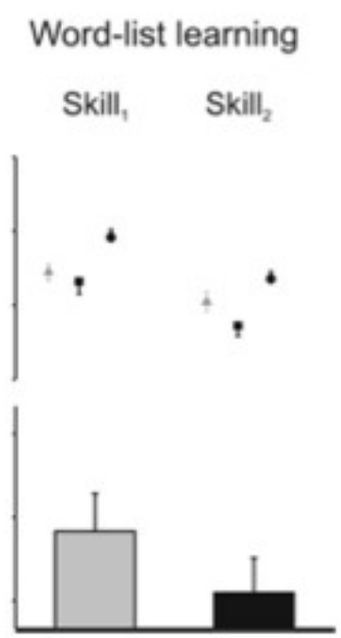
Overview

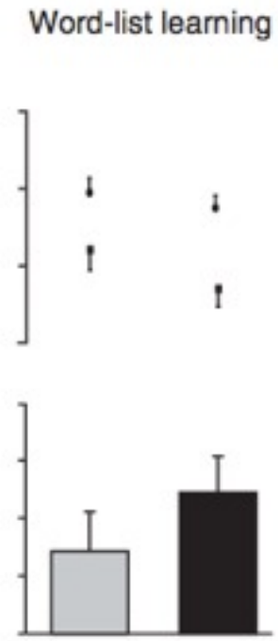
1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for ecological health
3. Future work
   - **Sequence learning / consolidation**
   - Walking and "higher-order circuits"
   - An example of a body-focused, conceptual intervention

Declarative Interference in Motor Learning

- 2 papers: Brown & Robertson (2007)
  - One appears to demonstrate interference
  - One appears to boost consolidation

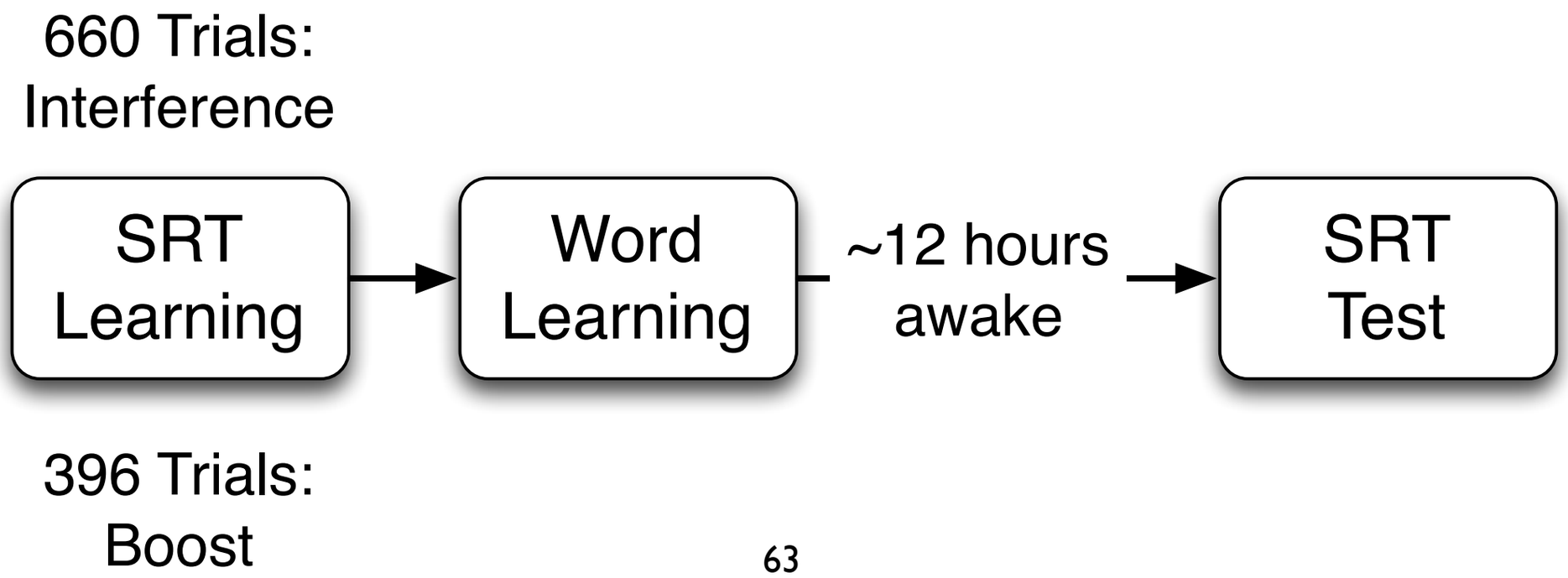
msec
"skill"





Declarative Interference in Motor Learning

- One (readily testable) interpretation:
  - Differing levels of practice shift the learned representations from more to less hippocampally dependent
  - cf. Kaisler & Shadmehr (2010) targeting "fast" (my "conceptual") learning



Overview

1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for ecological health
3. Future work
    - Sequence learning / consolidation
    - **Walking and "higher-order circuits"**
    - An example of a body-focused, conceptual intervention

Higher-level Brain Circuits in Walking Adaptation

- Morton & Bastian (2004): Walking prism adaptation:
  - Requires the cerebellum, and
  - Transfers to reaching
- But the nature of the "higher-order" circuits remains unclear
  - Might symbolic cueing also engage relevant higher-order circuits?
  - What about other forms of spatial navigation?

Overview

1. Why should a movement scientist care about climate change education?
2. Conceptual interventions for ecological health
3. Future work
   - Sequence learning / consolidation
   - Walking and "higher-order circuits"
   - **An example of a body-focused, conceptual intervention**

Get ready!

- I think it's important to provide an example an approach to motor learning from the Feldenkrais method
- It's hard to communicate some concepts without first having an embodied experience to refer to
- This will be pretty simple
- It's an exploration, so there's no specific "right way"
  - So, you can't "do it wrong" either!
  - Feel free to ask questions or simply observe

Using guided attention & exploration improves our abilities

- This general idea is nothing new
  - Kabat-Zinn's Mindfullness-Based Stress Reduction
  - Visual Attention (Liu, Pestilli, & Carrasco, 2005)
  - Sequence learning (Curran & Keele, 1993)
- But the richness of the target movements are novel
  - We might find a productive middle ground here between theory and practice!

Acknowledgements

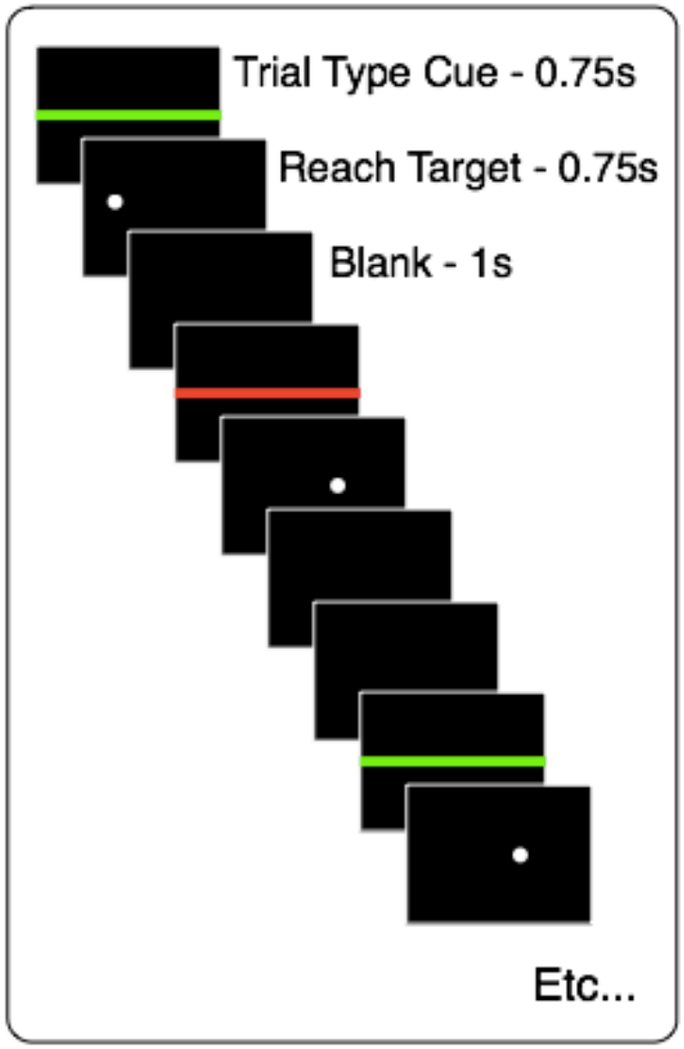
- Michael Ranney & the Reasoning Group
  - Direct contributors: Tawny Tsang, Daniel Reinholz, Sarah Cohen, Roxana Farjadi, Megan Beale, Amanda Cain, Denny Gillingham, Lloyd Goldwasser, Jackie Filipe
- Rich Ivry & the CognAc Gang
  - Direct contributors: Tawny Tsang, Becca Stoloff

Thank you!

How do neural circuits for world-oriented decisions compare to self-oriented decisions?

Pilot Experiment Design – Block Design

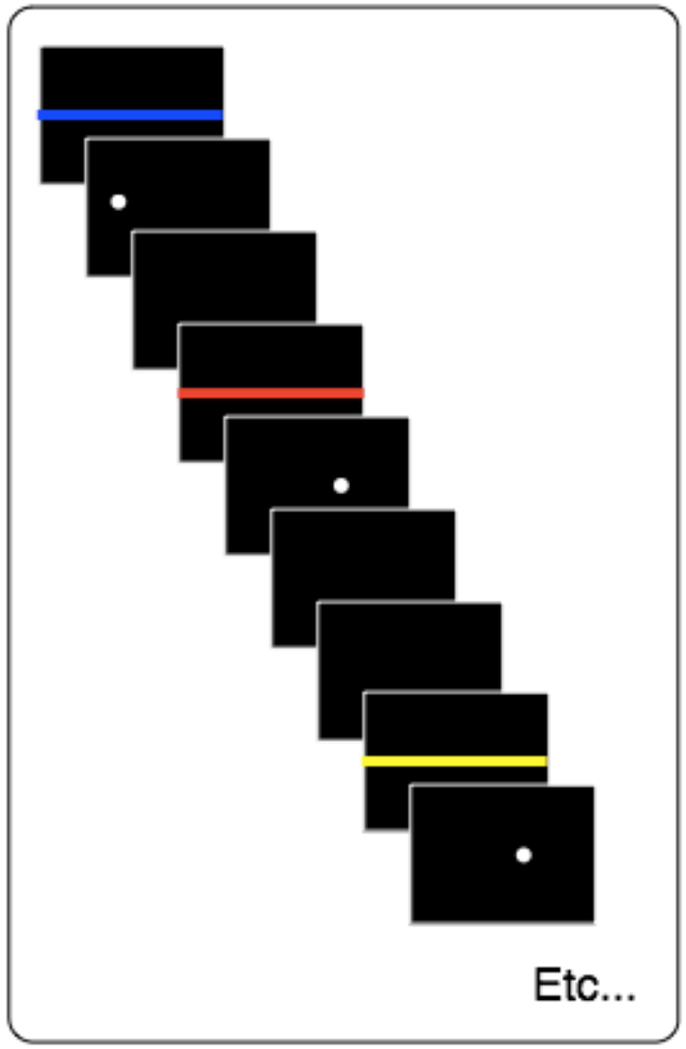
"Free" (green = right OR left hand)



Go
No Go

Free Choice Behavior

"Forced" (yellow = right, blue = left)



Right
Left
No Go

Pilot Experiment Design – Block Design

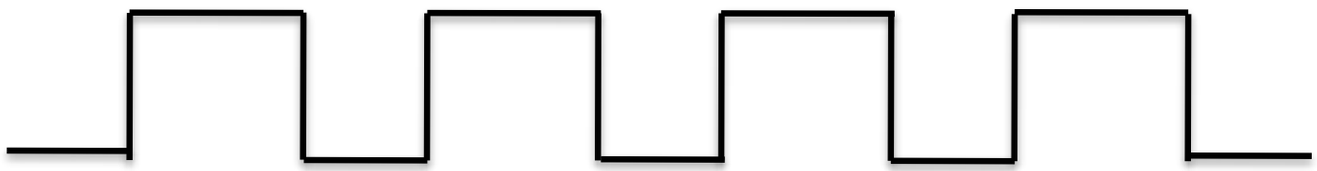
A: Free Choice, 14 Trials x 2.5 seconds/trial = 35 seconds

Go/NoGo (80/20)

B: Forced Choice, 14 Trials x 2.5 seconds/trial = 35 seconds

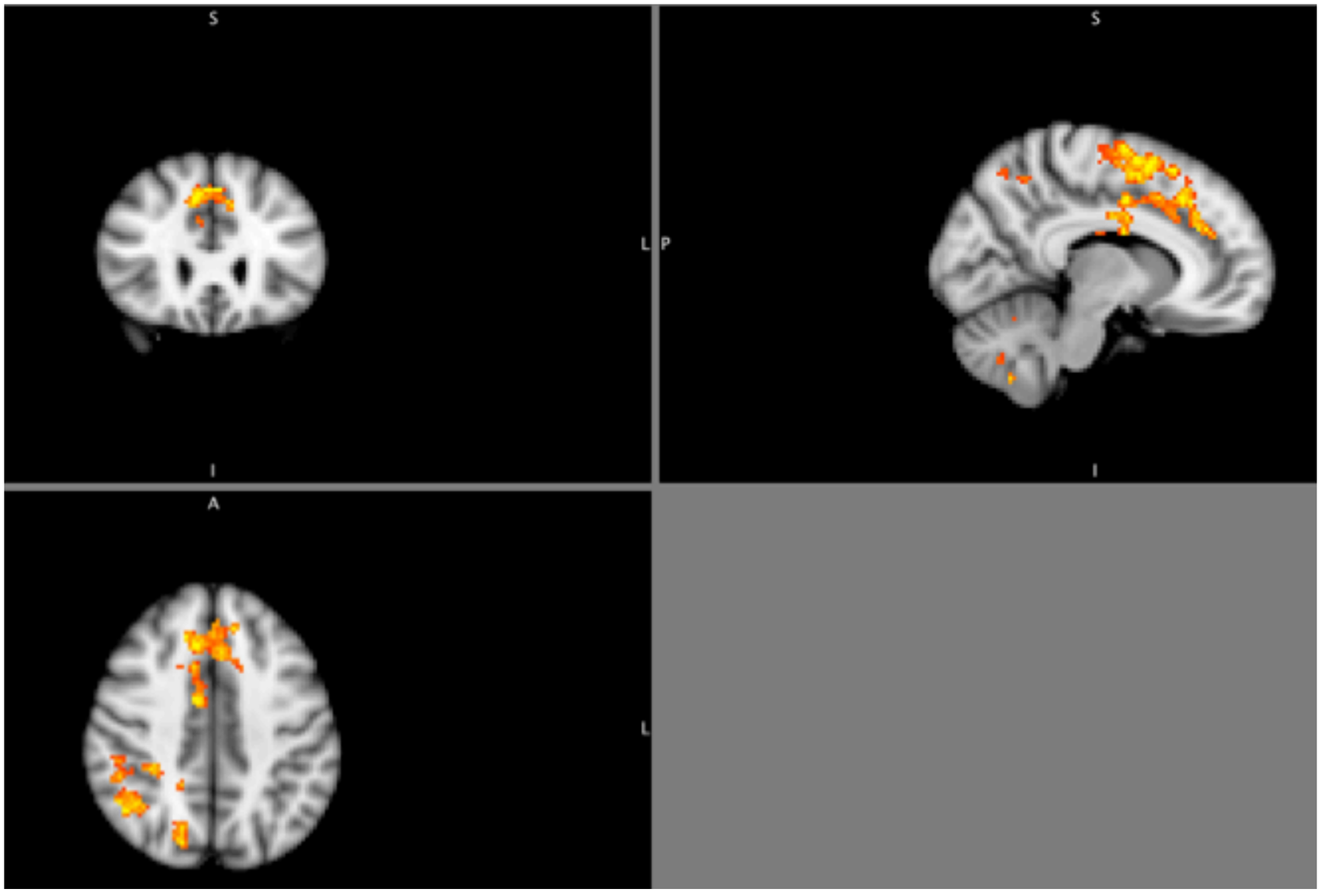
Prescribed behavior copied from preceding "A" block

Rest = 14 seconds



…Etc. (total 4 repeats)

Where is activity greater in “free choice?”

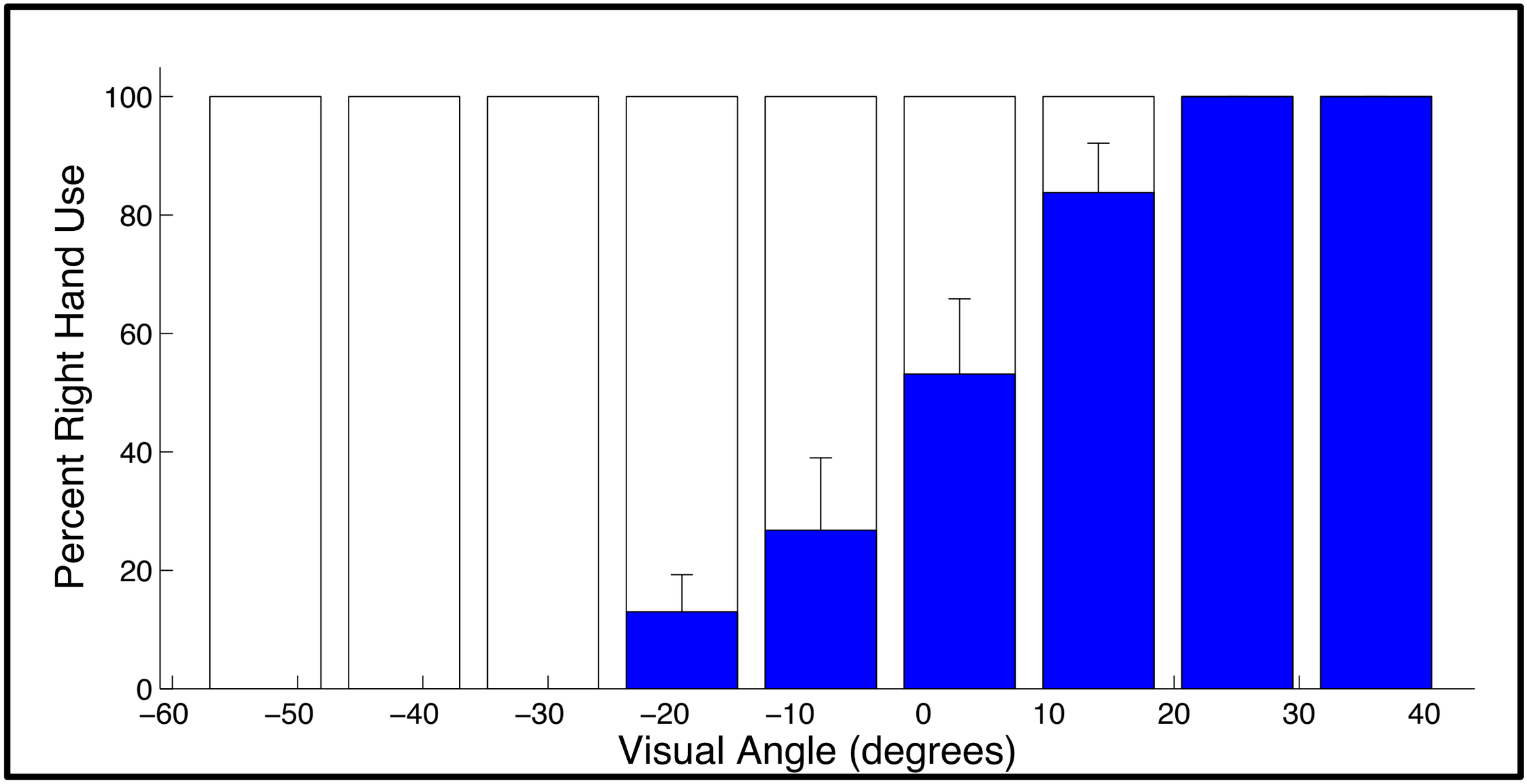


In short

- Body / self-oriented choice seems to engage similar “high-level” regions to world / goal-oriented choices

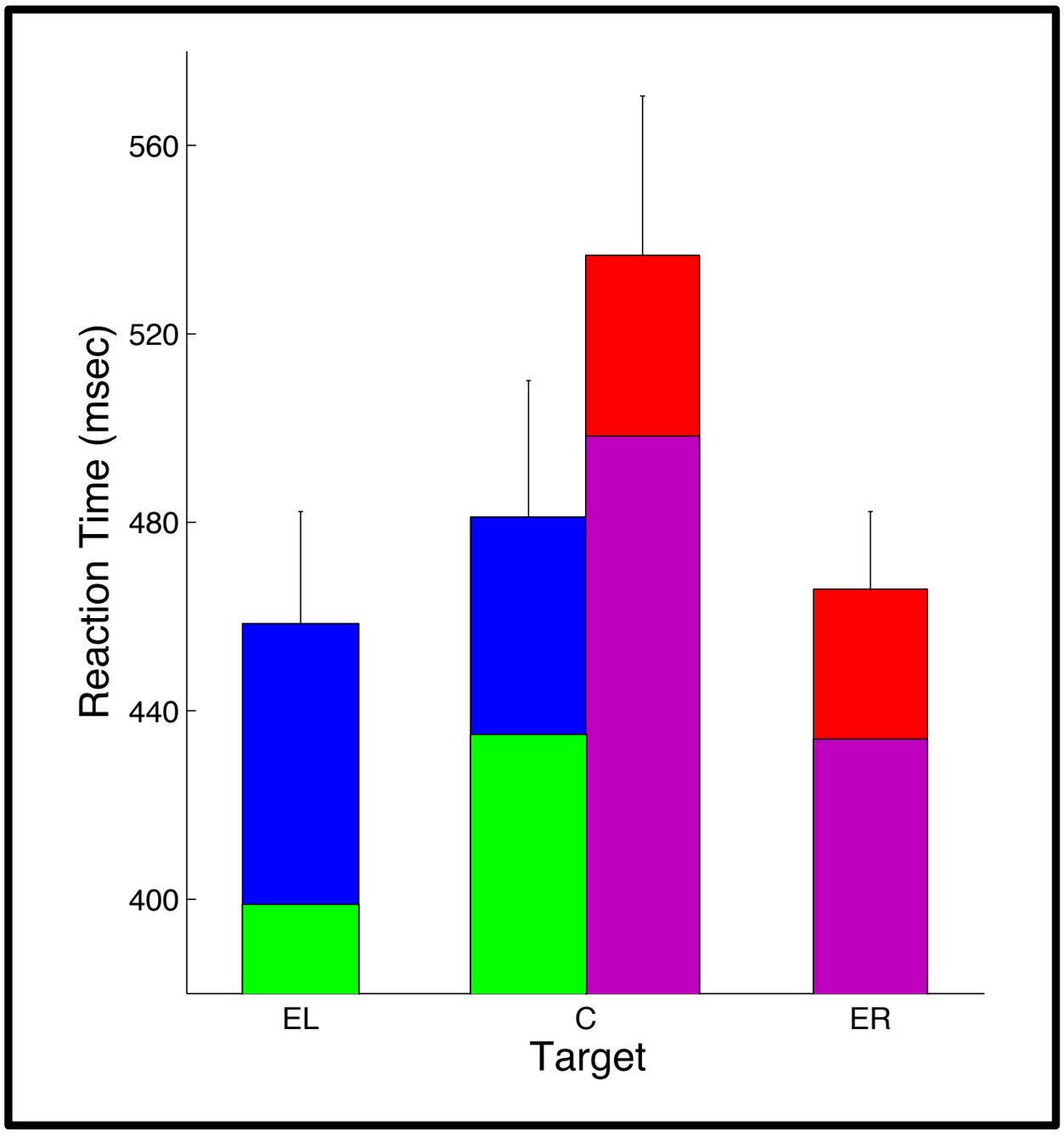
Behavior Results: Percentage Right Hand Use

n = 6



Behavior Results: Reaction Time

n = 6

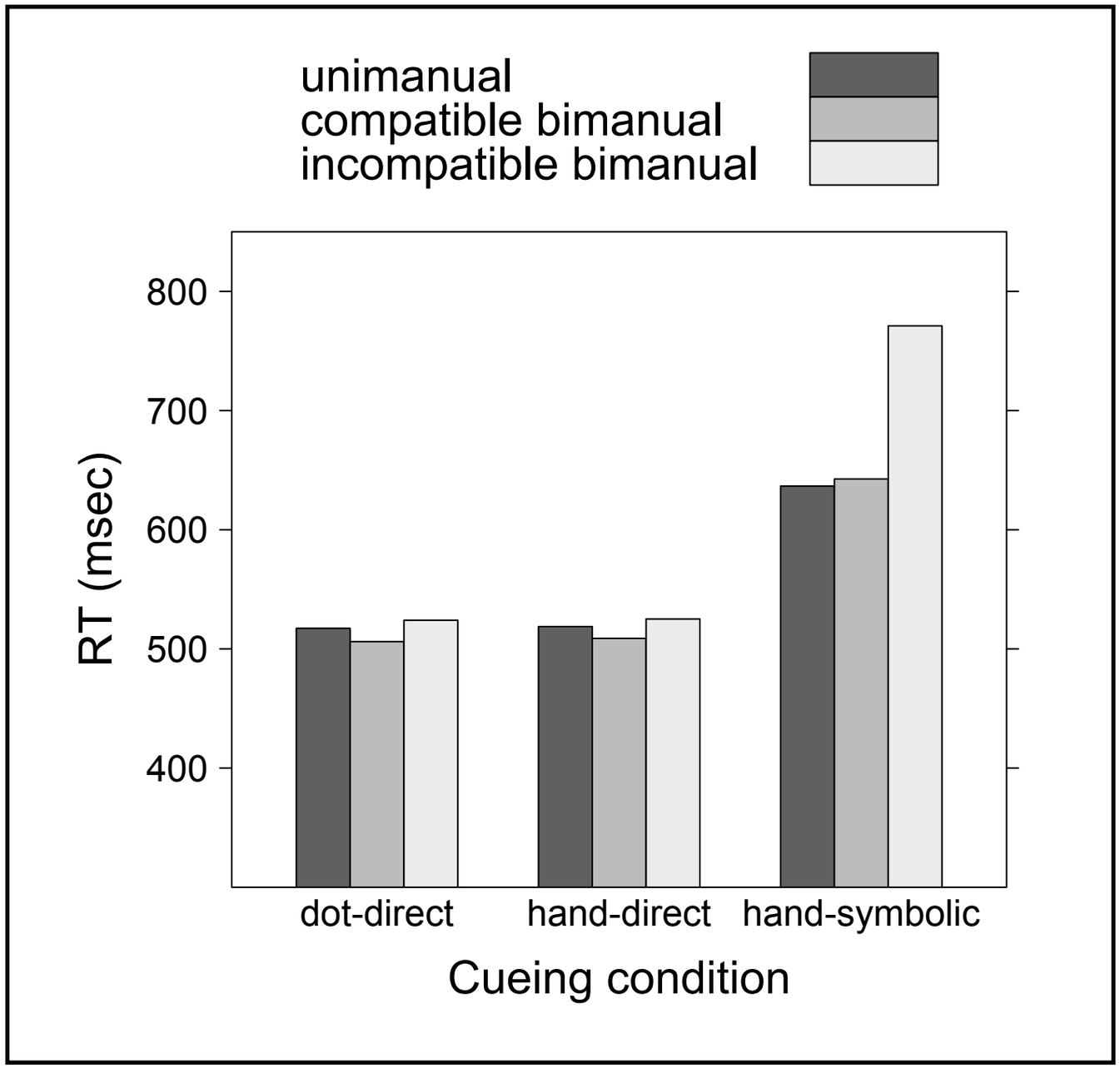


EL = eccentric left hand target
ER = eccentric right hand target
C = Central Target

Instructed Left
Instructed Right
Free Choice Left
Free Choice Right

What we did

- Three conditions on same aparatus
  - Reconstruction of hands, direct cues
  - Reconstruction of hands, symbolic cues
  - Abstract dots for hands, direct cues
- Order counterbalanced
- 1 practice, 3 “real” blocks (72 trials ea.)



What they did

What now?

- Virtual reconstructions *in this setup* aren't any better than dots
- What if we make the mapping harder? easier?

Two kinds of S-R incompatibility

- First-person vs. spatially transformed visual environment: In first-person virtual environments, individuals have no additional costs above "real-world" movement and reaction times for movement initiation can be as low as 350 msec (as in Diedrichsen et al., 2001). Individuals incur a cost of approximately 175 msec when the movement perspective entails some transformation from the first-person perspective.

- Spatially compatible stimulus-reponse mapping vs. abstract visual cues: When movement cues are abstract or indirect, individuals incur costs of approximately 125 msec, as well as yet further costs of approximately 100 msec (225 msec total) for bimanual movements that are spatially incompatible.

Approach

- Try to pinpoint learning that might improve an important real-world behavior
- Shift to a cognitive approach to the nature of that learning
- As with much of cognitive science, we leave the "real-world" somewhat behind

Behavior Change in America

- What's the problem?
  - –Americans frequently engage in behavior with potentially disastrous consequences for themselves, others and our environment.
- What do we know?
  - –People are *sometimes* irrational
    - Propaganda is effective!
  - –Multiple forms of processing / learning
- Can we use such knowledge to better characterize and ultimately improve learning (and thus yield educated decision making)?

A complementary approach

- The propaganda approach makes me sad
- Fortunately, there are many examples of successful *rational* educational interventions
  - Gigerenzer: can train Bayesian inference in one hour
  - Max Bazermen: overcoming biases with appropriate framing
  - Ranney, et. al.'s success with "Numerically Driven Inferencing"
- ***Plan:***
  - Take a closer look at the psychological basis of NDI
  - Proceed to develop targeted interventions

Estimate this:

According to the National Oceanic and Atmospheric Administration, the average global temperature changed ____ between 1940 and 1975.

+/- __deg. F

What would you think if the actual value were:

decreased by 0.2 degrees F?

…because it is!

One of our Recent Experiments: Merging Climate Education With "evil" NDI

We've Also Developed a "pro-Global Warming Acceptance" set of NDI facts

Based on a set of 1372 researchers who are actively publishing in the field of climate research, **98%** accept human-caused climate change (published in the Proceedings of the National Academy of Sciences).

According to a 2007 report, **11 of 12 years** between 1995-2006 (a 12 year period) rank among the hottest 12 years (since 1850) for average global temperature.

Atmospheric carbon dioxide levels have increased by **40%** from 1750 to 2010 (according to US Department of Energy).

Atmospheric methane levels (a greenhouse gas) have increased by **151%** since the year 1750 (according to a study published by the Royal Society of Chemistry).

NDI Experiments

- **Two variations**
  - **–2-item – Like our "Sandwich" Mechanism condition**
    - **»Knowledge & Attitudes pre-test**
    - **»2 estimation items w/ "why" short answer questions**
    - **»Knowledge & Attitudes post-test**
  - **–8-item "blast" – Like our "No Pre-test" Mechanism condition**
    - **»8 estimation items**
    - **»Knowledge & Attitudes post-test**

Key NDI results

- **Acceptance drops from 6.5 pre-test to:**
  - **6.2 on 2-item survey (6% of available)**
  - **5.9 on 8-item survey (12%)**
    - **Imagine the policy implications of this size of movement**
- **Self-rated knowledge drops from 5 pre-test to:**
  - **4.5 on 2-item survey (12%)**
  - **2.9(!) on 8-item survey (53%)**