Design Cognition

CIS 7000-001

Andrew Head and Danaé Metaxa

Announcements

Quiz deferred to Thursday, Jan. 29.

- Sample quiz posted on Ed
- Quiz takes place at the start of class.
    - Arrive on time to get the most time to take the quiz

Reading responses: I want to challenge you all to engage more deeply with the future work. This means thinking about open research questions deserving of thorough inspection, and not just applications.

Good engagement with future work

“The implications for AI interfaces seem worth considering, though I am not sure Norman's framework translates cleanly… Norman’s feedforward mechanisms assume a bounded set of actions that can be communicated through signifiers and constraints, but when the action space is open-ended natural language, those mechanisms do not really apply. Future work might **explore how to signal capabilities in systems** where the functionality is not fixed. **Suggested prompts and example interactions are one approach**, but I am skeptical that these solve the underlying problem, because the capabilities of these systems are emergent and context-dependent in ways that static signifiers cannot capture…”

Ubiquitous computing

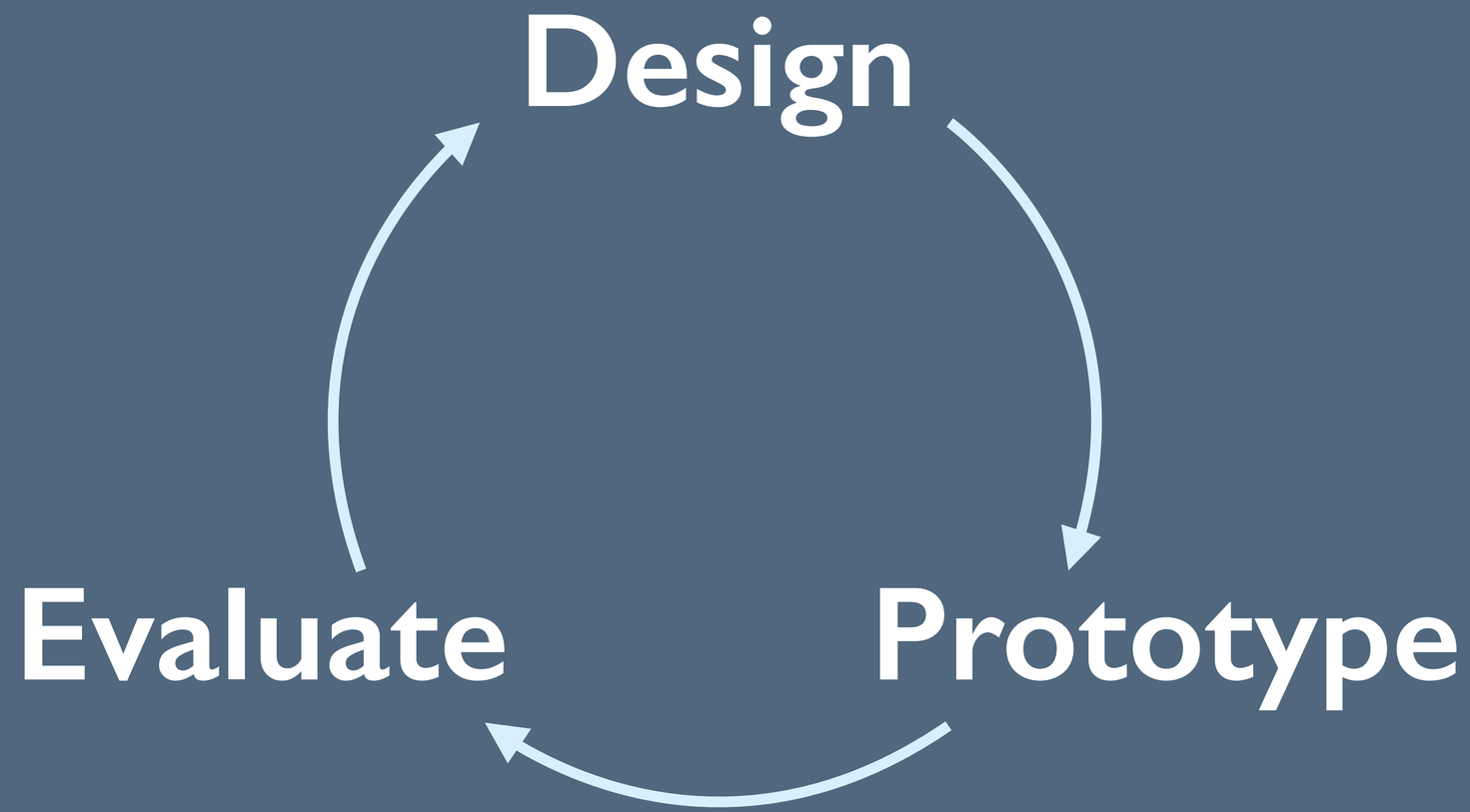
Unit 1

ubiquitous and tangible computing
input and output
activity sensing

Design

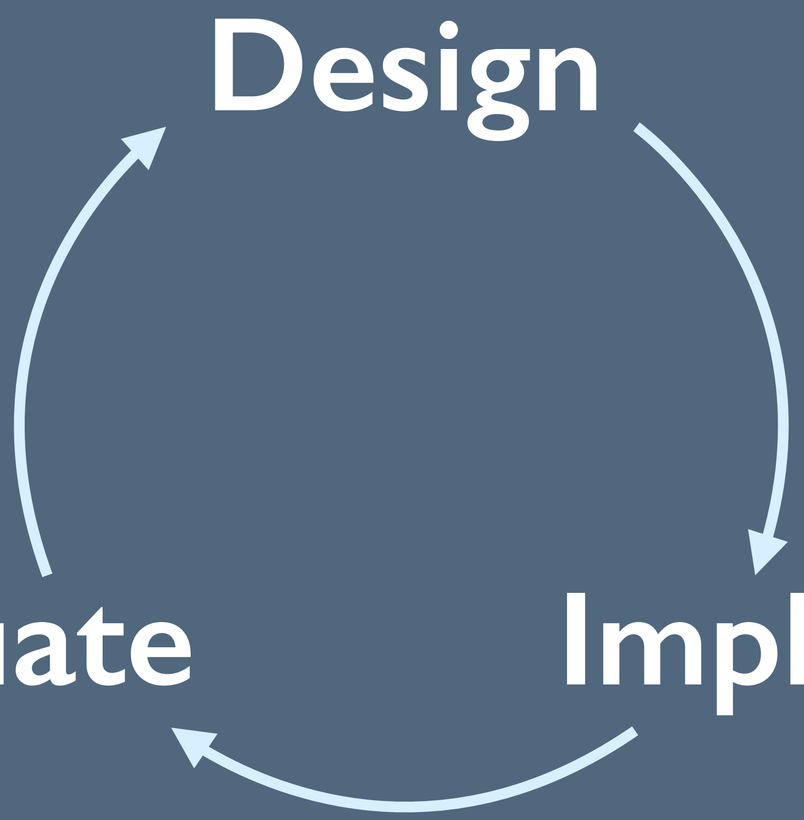
Unit 2

design cognition
design process
design tools

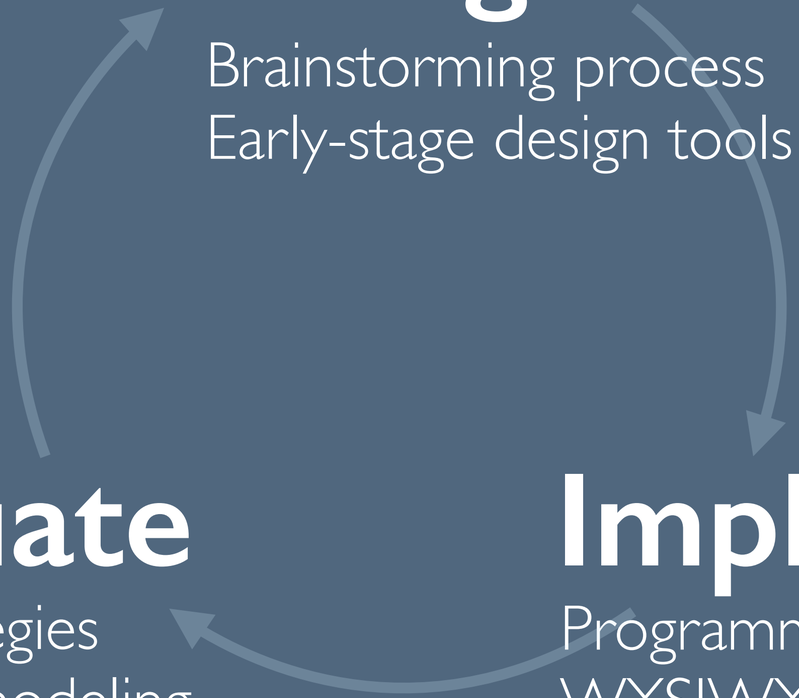

Design
Prototype
Evaluate

Design is not a fixed process.

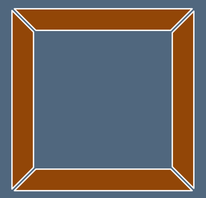
It can be studied, supported, and improved.



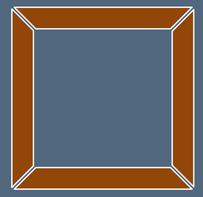
How might we facilitate and empower this process?


Design
Brainstorming process
Early-stage design tools
Implement
Programming tools
WYSIWYG design tools
Rapid prototyping tools
Evaluate
Study strategies
Cognitive modeling

Most “meta” lecture of this course

Framing, Part I 

- When we build systems in HCI, we are often implicitly trying to help people with design (to solve poorly-defined problems with substantial creative aspects). This lecture helps you **identify the role your system will play in helping them succeed**.
  - This will be clearer in the next two lectures.
- We in HCI are constantly dissecting what went wrong/right in computer systems. This lecture gives you **vocabulary to start doing those dissections yourself**.
  - This will be valuable for *all future lectures*.

Framing, Part II 

Broadly, learn to see **gaps in process and outcomes**, and explore **new kinds of process innovations (methods + tools)**

In the process, refocus from descrigin **process** of design (a la CIS 4120) to the **principles** that shape that process.

Today

Design cognition: how our thinking shapes our design process, and how our thinking shapes others' reactions to our designs

Three major themes of design cognition:

Design fixation

Analogical transfer

} Why you don't get what you want out of the design process

Gulfs of execution and evaluation

} How to argue why a design is (or is not) better

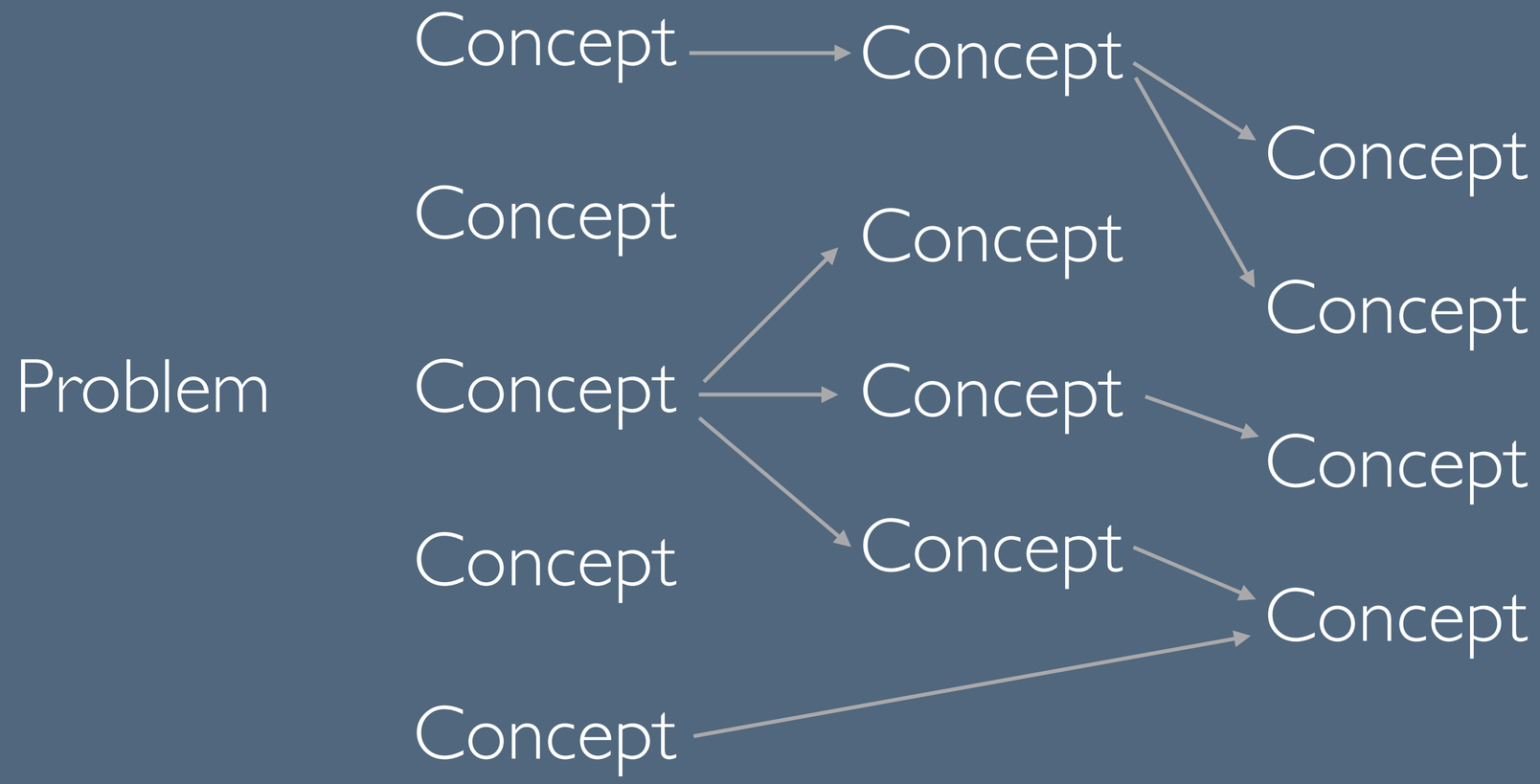
Why You Might Not Get What You Want

Part I

Design Fixation

Ideal: open-minded ideation

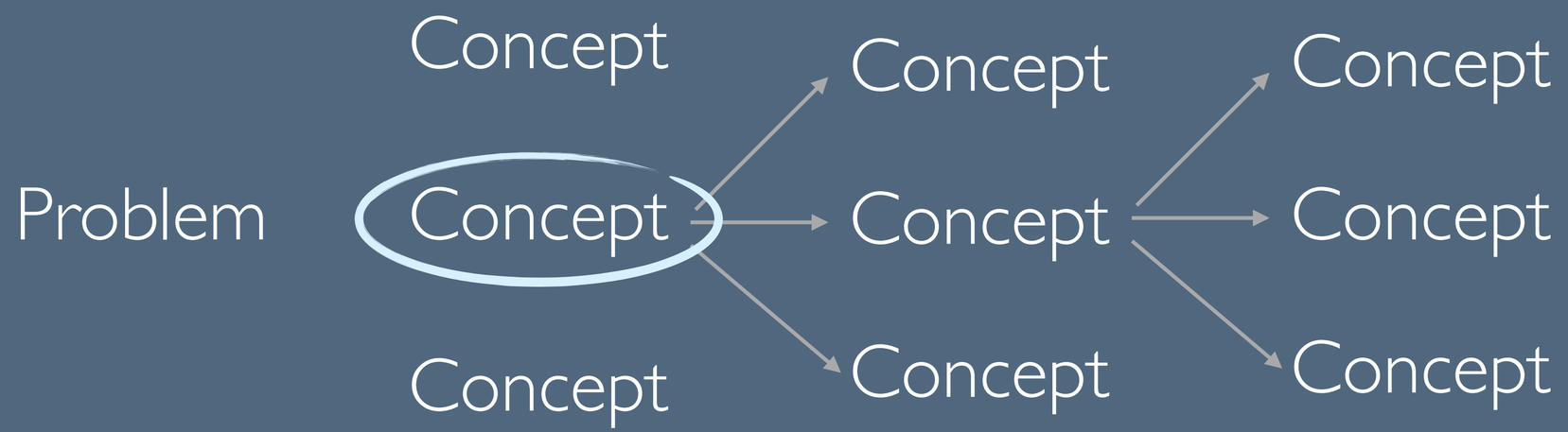
In theory, the ideation process identifies many ideas, both proximal and distal



Reality: not enough breadth

In practice, we often myopically stay near proximal concepts that we've used before or that are surface-level similar

Why?



"I always liked this one anyway"

Design fixation

It cognitive psychology, **fixation** is when we introduce self-imposed barriers to problem solving [Maier 1931, Luchins 1942]

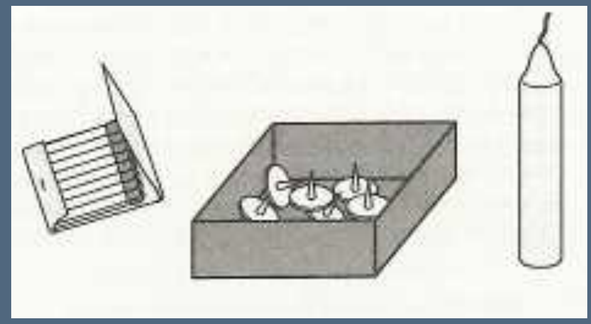
Design fixation is when we limit the breadth of our design process through adherence to a small set of concepts [Jansson and Smith 1991]

Design fixation takes hold both (1) unconsciously, when we're not aware, and also (2) consciously, even when we're aware that we're doing it.

Classic example of fixation

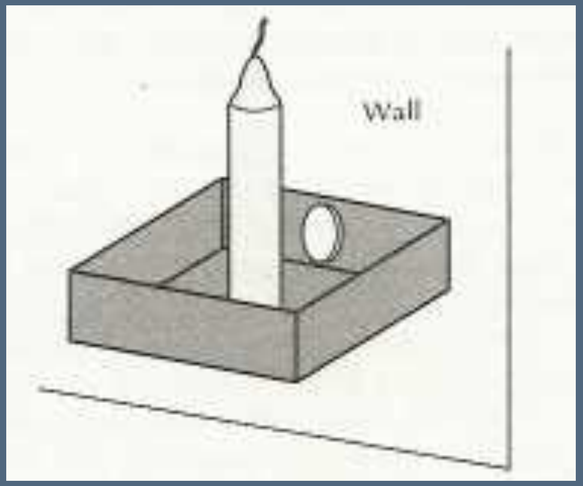
[Duncker and Lees 1945]

Goal: attach a candle to a wall so that the candle won't drip on the floor. You can only use (1) a book of matches, (2) a box of thumbtacks.



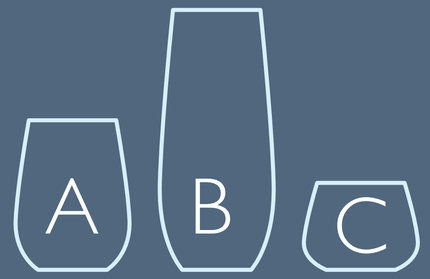
Designers are trained to question assumptions, and to creatively recombine the tools at their disposal.

However, we are biased toward using objects only in the ways we've seen them used before.



Classic example of fixation 2

[Luchins 1942]



Goal: measure a specific amount of water with the jars

Method: participants were given **practice tasks** that could be solved via a nontrivial algorithm B-A-2C

The **test problem** could be solved via the nontrivial algorithm (B-A-2C) but also very simply (A+C).

70% still used the nontrivial algorithm.

[Professor Layton]

The additional practice **should have made us better**. But, due to **fixation** on the approach we knew about, it made us **worse**.

Even worse, we fall in love with our own ideas

The IKEA Effect [Norton, Mochon, Ariely 2012]: **we place high value on things that we helped create**

> Experiment: One group of people build a piece of IKEA furniture, the control group get it pre-assembled. Both are asked how much they'd pay for the furniture.
>
> Those who assembled their own box were willing to pay a 63% premium over those who received the same furniture pre-assembled

Ideally, showing other peoples' ideas should positively influence our ideation. Instead, **we tend to ignore others' ideas**—unless the person who came up with them joins our design team. [Choi and Thompson 2005]

The harms of design fixation

Fixation anchors us in a small subset of the design space, preventing us from identifying the best solution

Knowing that it's happening doesn't help us escape it

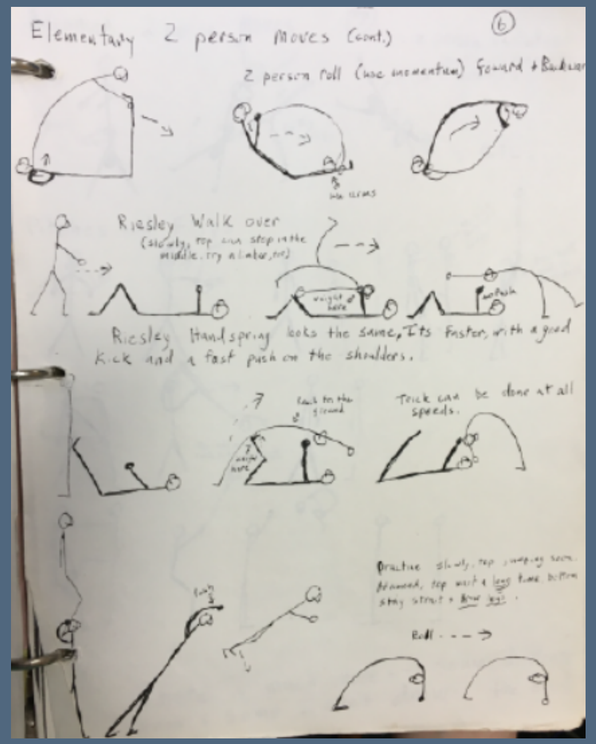
What does help us escape it?

sneak peek: design process 👀

Process interventions: dealing with fixation

Strategic forgetting

Some designers and creative professionals practice **strategic forgetting**, where they intentionally don't capture ideas immediately, and trusting that good ideas will come back multiple times [Nicholas, Sterman, and Paulos 2022]

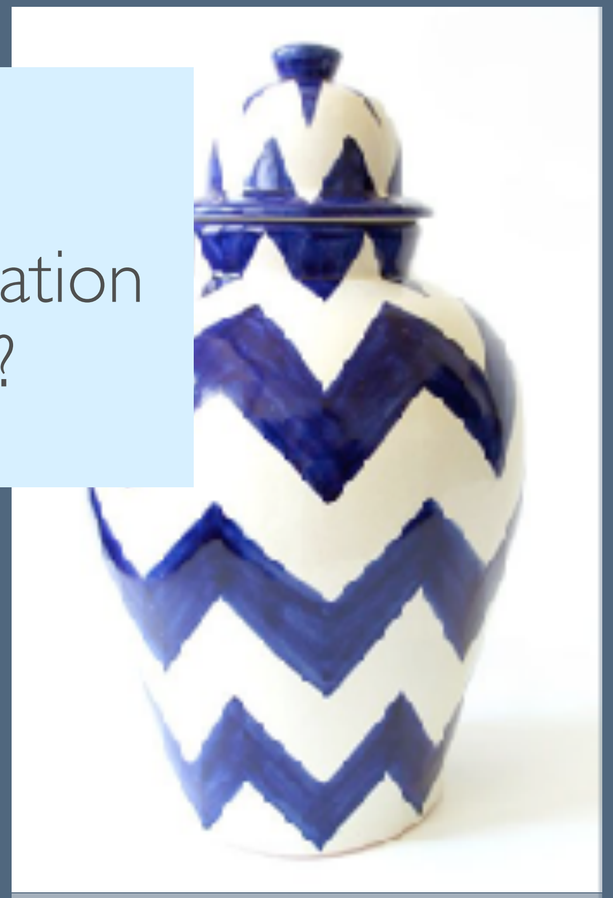


"Performance Director : [My mentor] would say "Here's the scene, try it," and then I would do it... he would not let me write it down in rehearsal. **[He would] say "write the scene up tonight," on the theory that whatever I remembered was worth keeping from the scene.** Which I found incredibly frustrating. But it

Quantity or Quality?

[Bayles and Orland 2001]

Can forcing yourself to try multiple options combat fixation and produce better designs?



Quantity or Quality?

[Bayles and Orland 2001]

"While the quantity group was busily churning out piles of work—and learning from their mistakes—the quality group had sat **theorizing about perfection**, and in the end **had little more to show for their efforts than grandiose theories and a pile of dead clay**"

Parallel prototyping

[Dow et al. 2010]

serial prototyping condition

parallel prototyping condition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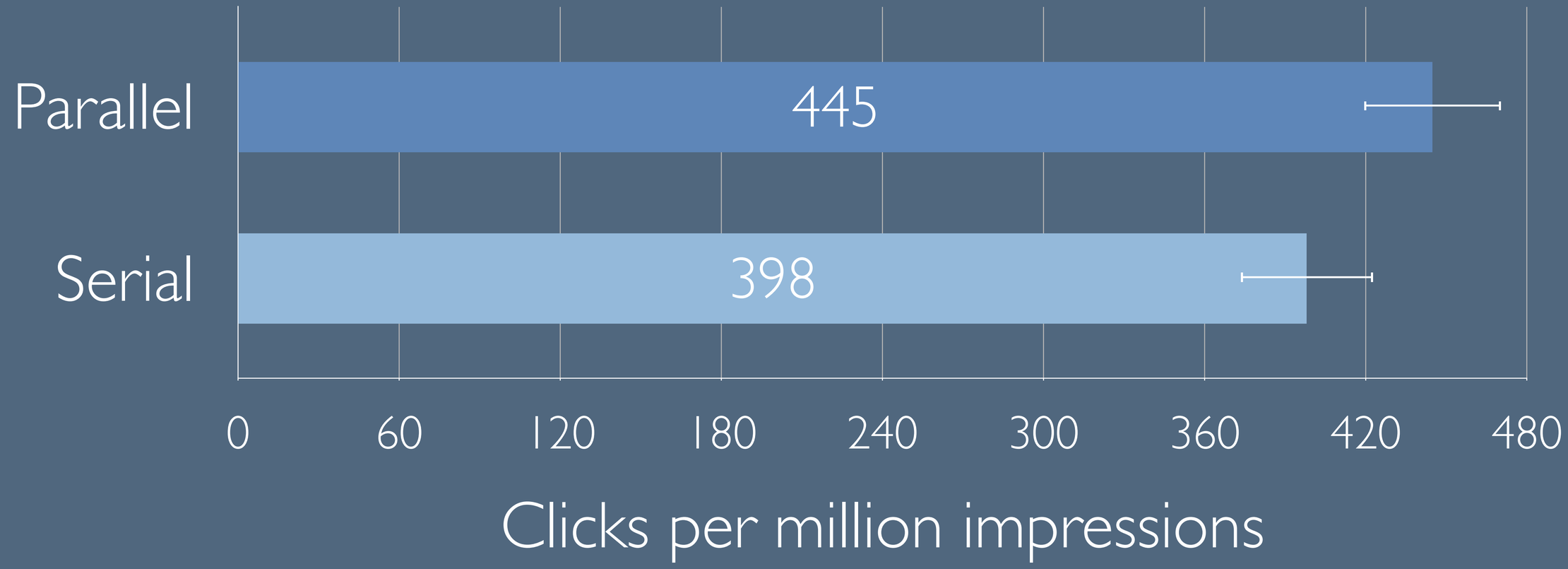
answer
(or left)
sides
brain
Read
other hand

Parallel design → more clicks



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Leveraing others to overcome fixation

Others can point out opportunities we don't see. They can also challenge assumptions that we hold dearly.

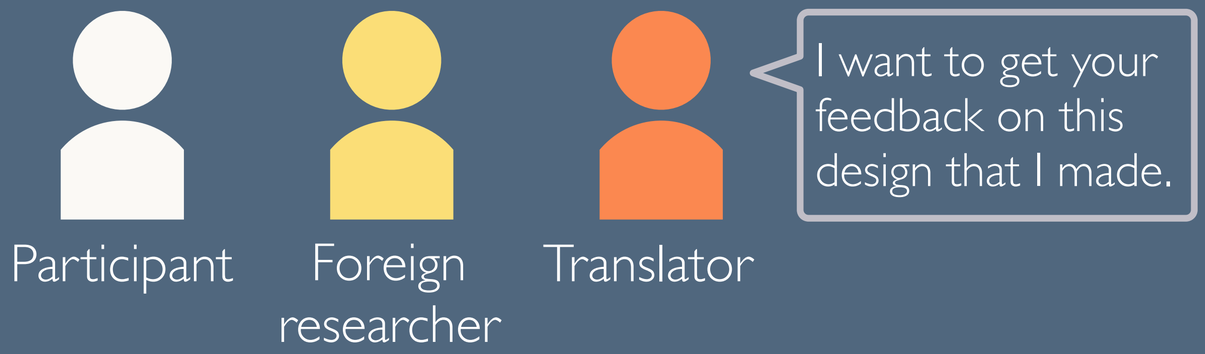
But there is another problem that arises when we solicit input on our designs without being careful…

Demand characteristics

[example from Dell et al. 2012]

Response bias due to signals in a study that indicate what the researcher is hoping to see.

2.5x more preferred amongst low-status participants



5x more preferred amongst low-status participants

Demand characteristics

[Dell et al. 2012]

The effect was so strong that with a foreign researcher and low-status participants, half of them preferred the researcher's lower quality video over the alternative higher-quality video

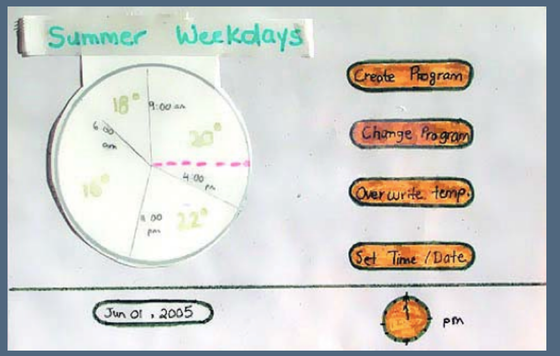
Quantity's role in calibrating feedback [Tohidi et al. 2006]

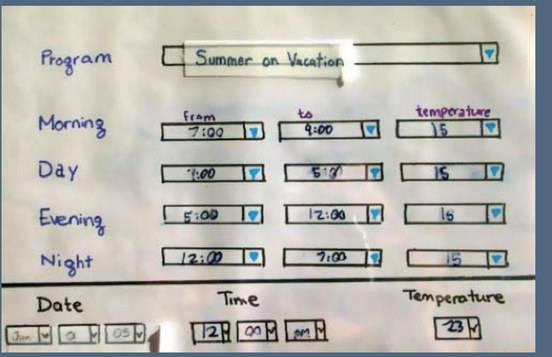
Prior practice: create one prototype, then show it to people to get feedback. But is this really optimal?

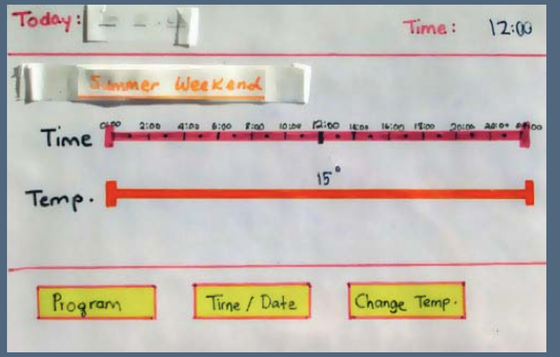
Study design:

- Method: show participants low fidelity prototypes for a redesigned smart thermostat and ask for feedback
- Control: show participants just one design ("the best")
- Treatment: **show participants three designs**

Measure: quantitative ratings of the design, as well as valence of the verbal feedback





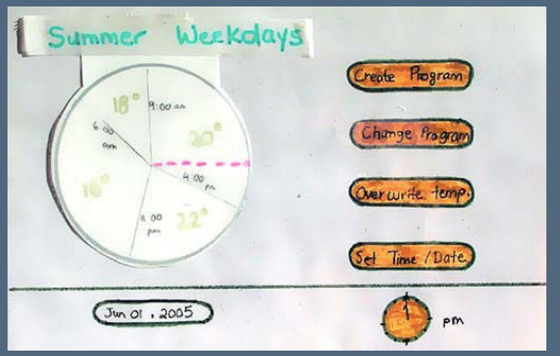


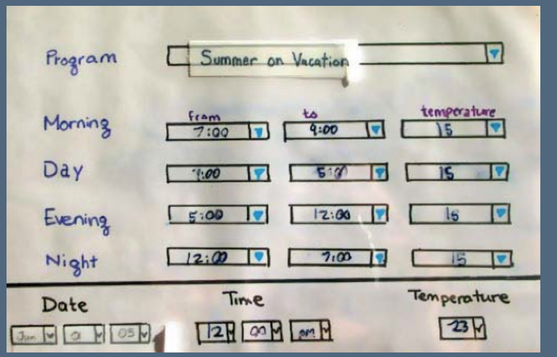
Quantity's role in calibrating feedback [Tohidi et al. 2006]

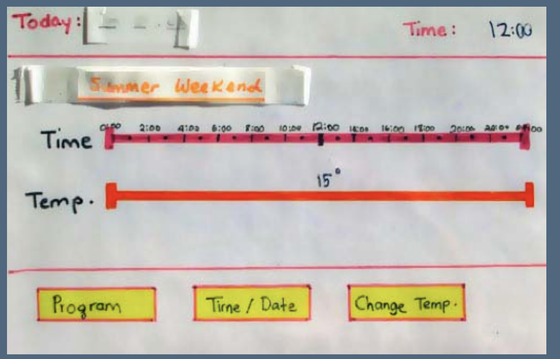
"We found that **when presented with a single design, users give significantly higher ratings and were more reluctant to criticize** than when presented with the same design in a group of three."

Why?

Weakening demand characteristics







… another reason you might not get what you want from your designs

Analogical transfer

Where do good ideas come from?

It's often easy to translate a solution from one problem to another problem if the **surface features** of the problems are similar.

Worked-out textbook solution

Test problem following the exact same format

But, major innovations are not such simple copy-pastes. They require mapping **deep features** between problems.

Fitting a solar array in 1/10th the size for takeoff

Origami

[Zirbel et al. 2013]

How do bacteria mutate?

Slot machines

[Murray 2016]

Analogical transfer

Transfer across these deep structures is referred to as **analogical transfer**, as in **transfer via analogy**

How? We abstract problems and solutions we've encountered into **schemas** that drop out surface features and facilitate comparison

Example

Problem: In embodied VR it is **difficult to work with objects that far away** from the user's avatar

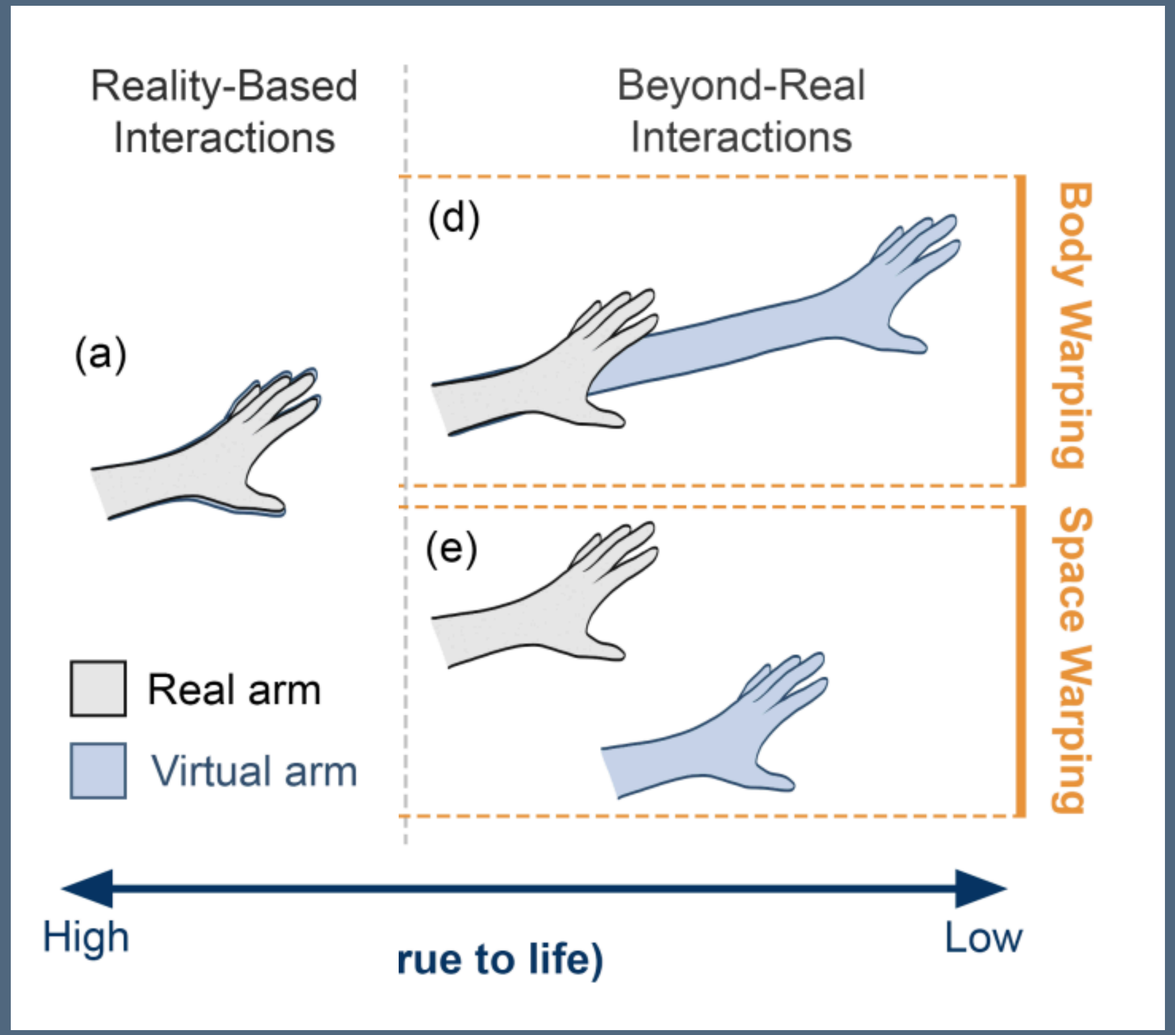
Surface feature transfer (boo): adapt laser pointer metaphor to VR

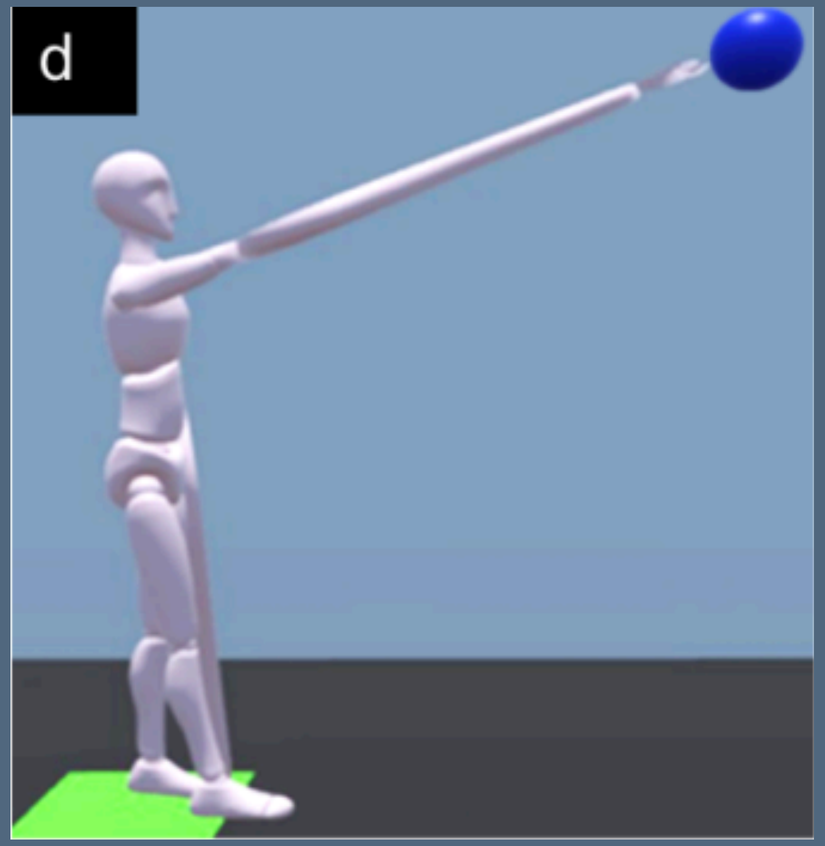
Deep feature, schema-based transfer (yay):

Social computing article: "Beyond Being There" [Hollan and Stornetta 1992] says to create collaborative experiences better than "being there"

Schema: Problem = adherence to reality is unsatisfying
Solution = stop trying to be realistic

Result: "Beyond Being Real" [Abtahi et al. 2022], create VR experiences that break from realistic self-representation





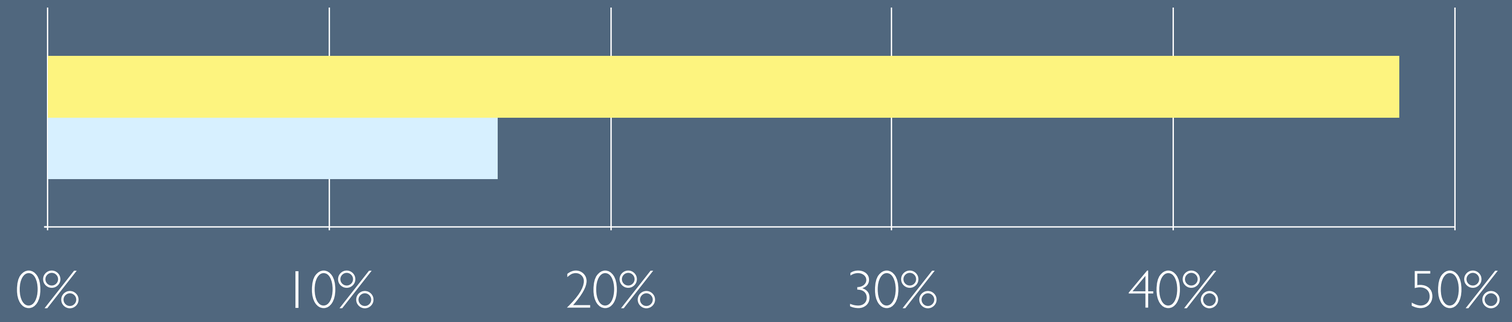
"Beyond Being Real" [Abtahi et al. 2022]

Without scaffolding, people don't identify deep features

Study: participants learning negotiation strategies

"Read these one at a time" vs "Compare these examples"

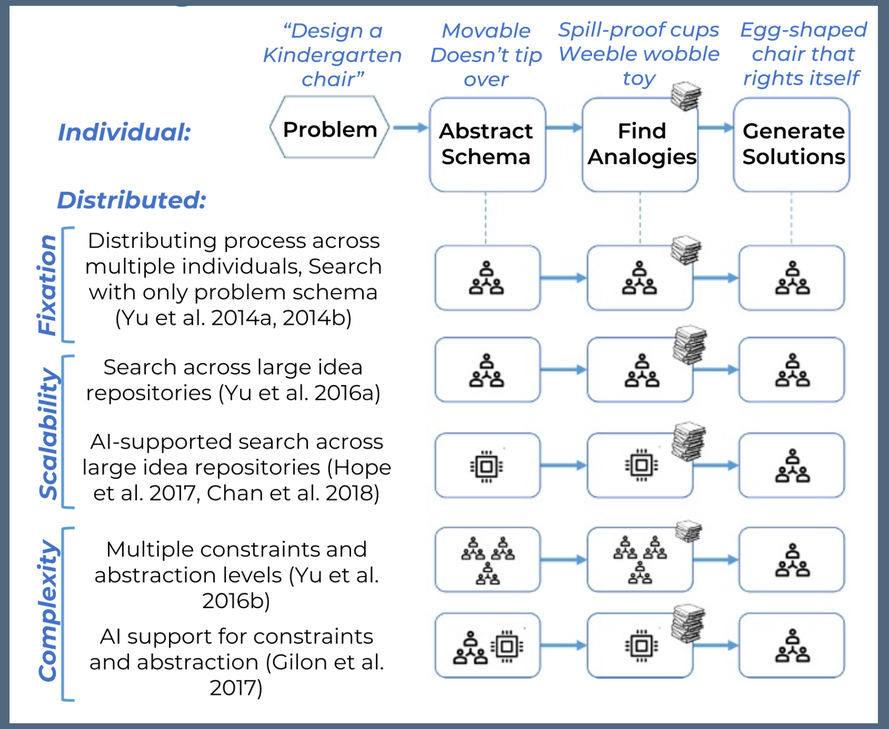
Measure: % of participants who correctly transfer the negotiation principle in the examples to a test case



Implications for design

Bad ideas are often a result of poor analogical transfer: applying surface features rather than deep features in retrieving relevant ideas

On the other hand, this raises opportunities: we can develop techniques to extract schemas at scale from existing ideas and aid application to new problems [Kittur et al. 2019]



How to Argue Why A Design Is (Or Is Not) Better

Part II

Gulfs of Evaluation and Execution

Goal: a cognitive account of why a design is poor

When people "don't get it", what's actually happening?

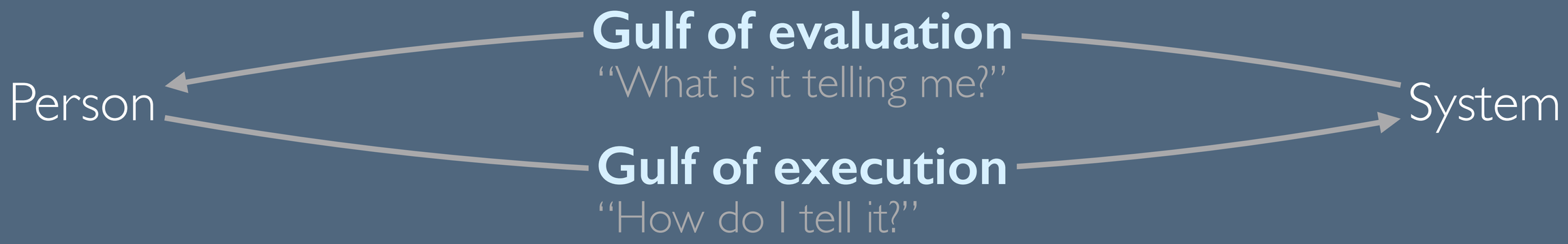
When people do get it can we say more than : "It just feels **natural**"

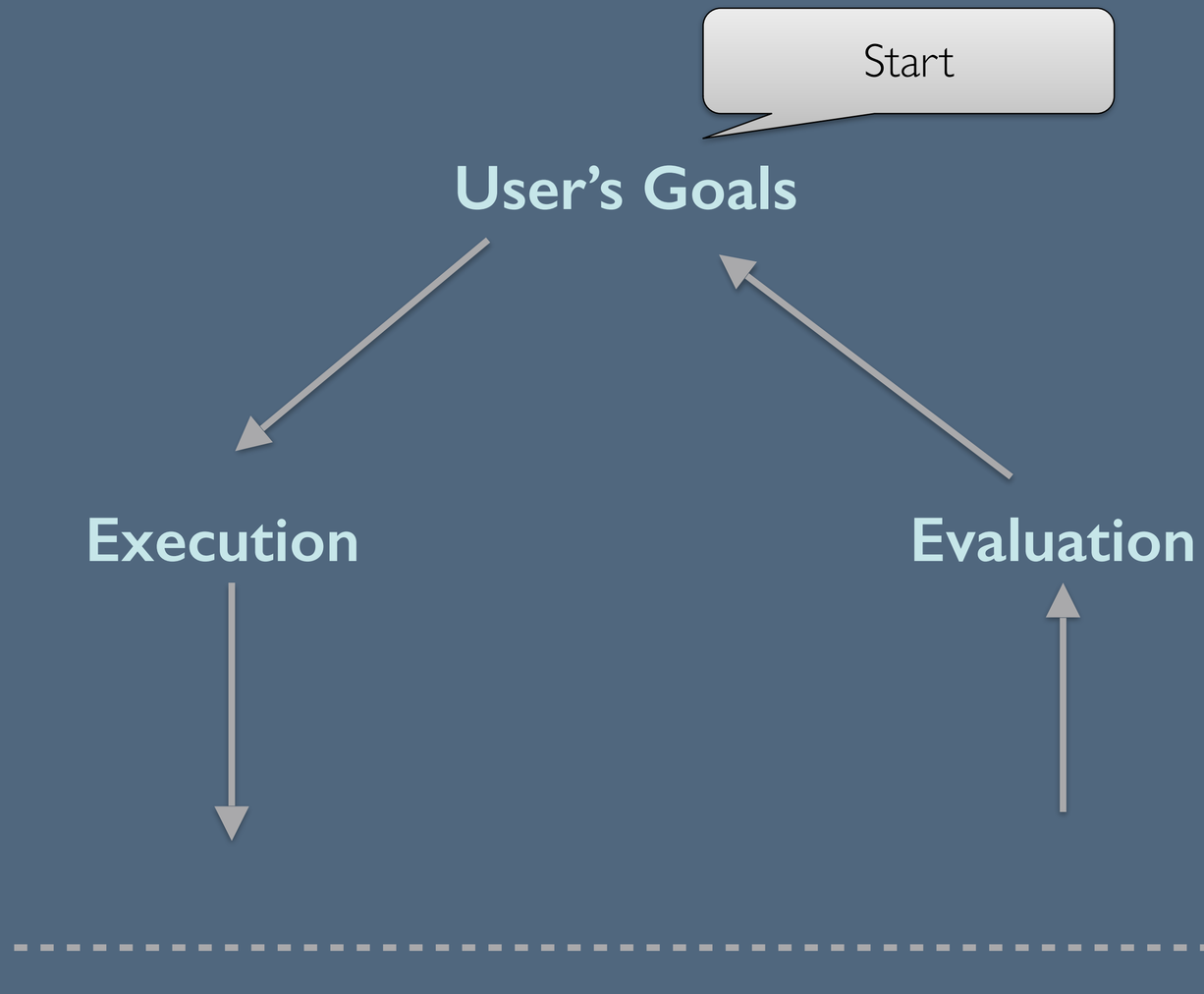
[Microsoft]

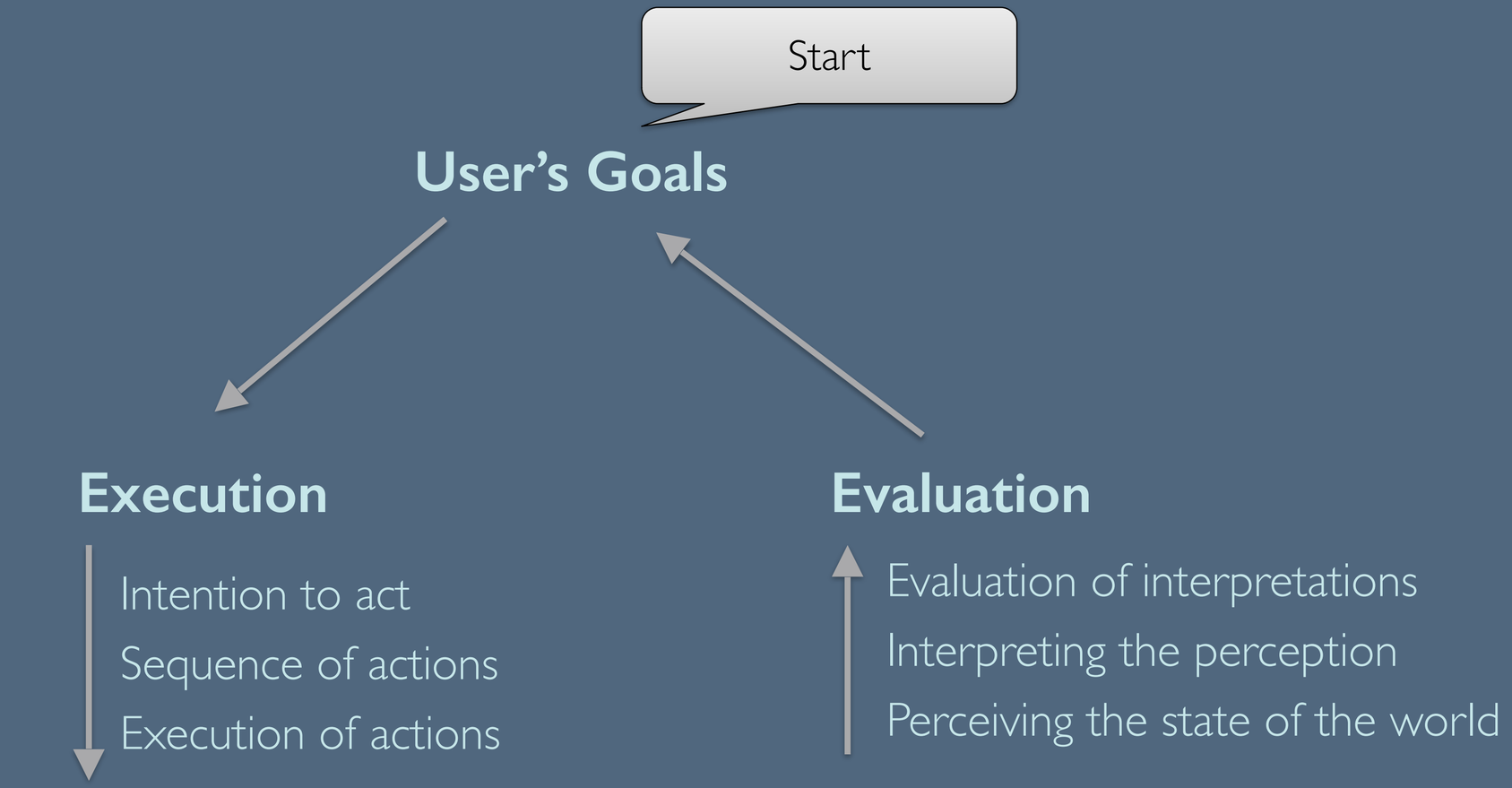
Gulfs between the person and the system

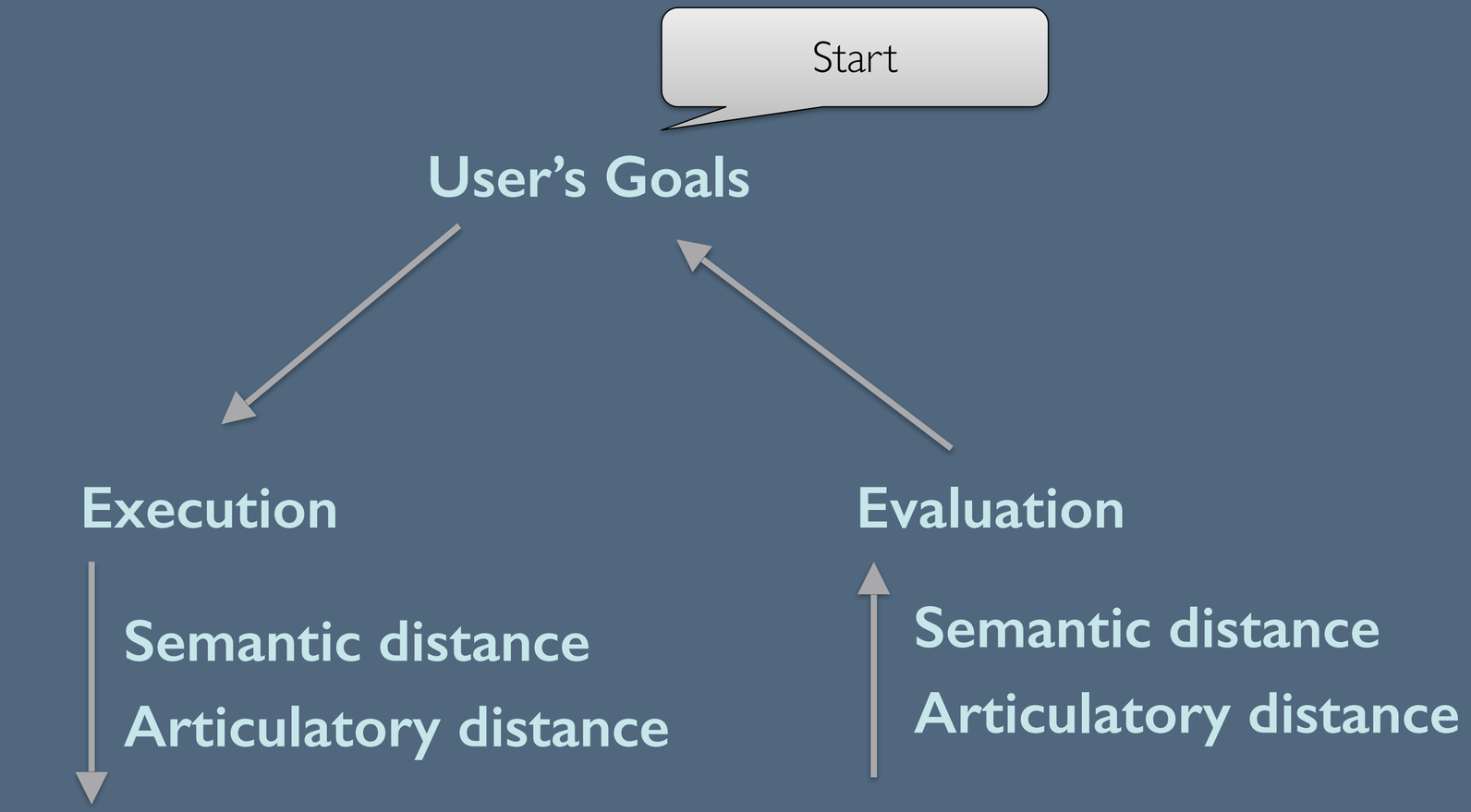
[Hutchins, Hollan and Norman 1985]

How many cognitive resources do I need to devote in order to translate from my goals to instructing the system and how do I interpret its output?




Start
User's Goals
Execution
Evaluation
System


Start
User's Goals
Execution
Intention to act
Sequence of actions
Execution of actions
Evaluation
Evaluation of interpretations
Interpreting the perception
Perceiving the state of the world
System


Start
User's Goals
Execution
Evaluation
Semantic distance
Articulatory distance
Semantic distance
Articulatory distance
System

Distances, Coarsely

Roughly speaking, the distances can be described as…

semantic distance comes from mismatch between system representations and how the user thinks about the problem.

articulatory distance comes from work involved in speaking and understanding the system on its own terms.

Distances across the gulfs

semantic distance comes from mismatch between system representations and how the user thinks about the problem.

exec: how do I make the system do this?

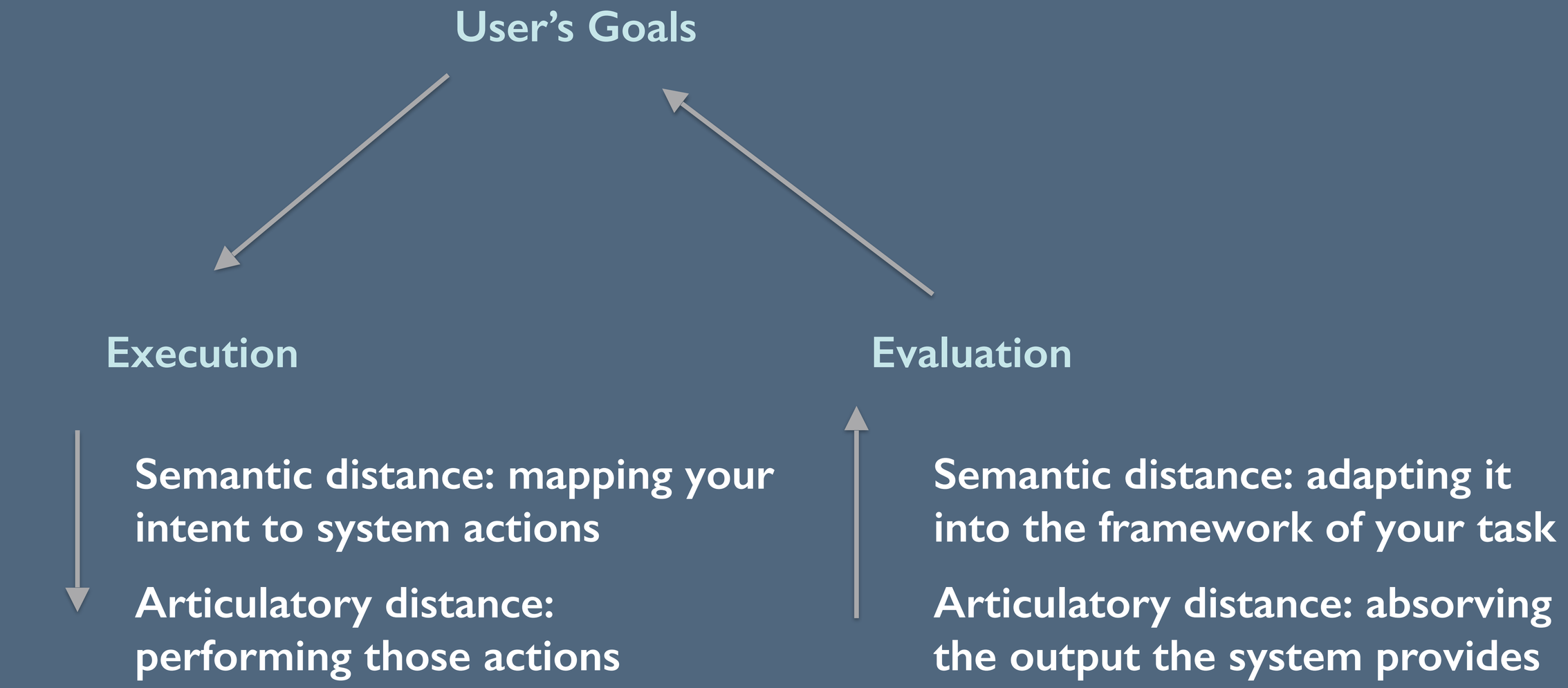
eval: what does this output tell me towards achieving my goal?

Distances across the gulfs

articulatory distance comes from work involved in speaking and understanding the system on its own terms.

exec: performing actions (commanding, triggering)

eval: extracting signal from the system (finding resulting info, scanning, deciphering on system's terms)


User's Goals
Execution
Evaluation
Semantic distance: mapping your intent to system actions
Articulatory distance: performing those actions
Semantic distance: adapting it into the framework of your task
Articulatory distance: absorving the output the system provides
System

Always know which gap you're dealing with

If someone has to sit and figure out how to parse the symbols the system is presenting:

gulf of evaluation
(an articulatory distance)

If someone can decipher the symbols are, but can't figure out how the symbols relate to their goals:

also a gulf of evaluation
(but this time a semantic distance)

Always know which gap you're dealing with

If a nontechnical user knows which machine learning model they want to use but have to build it with raw tensors and have no idea how

gulf of execution (a semantic distance)

If that nontechnical expert has the right idea of what to command the system to do, but the function call is complicated (e.g. many parameters)

also a gulf of execution (but this time an articulatory distance)

Which gulf and distance is each design trying to address?*

Swype keyboard

Glanceable data summaries (vs. raw data)

London Tube map (vs. geographic layout)

DSLs (e.g., Python pandas `df.groupby('column').mean()`)

	Gulf of Evaluation	Gulf of Execution
Semantic distance		
Articulatory distance		

Which gulf and distance is each design trying to address?

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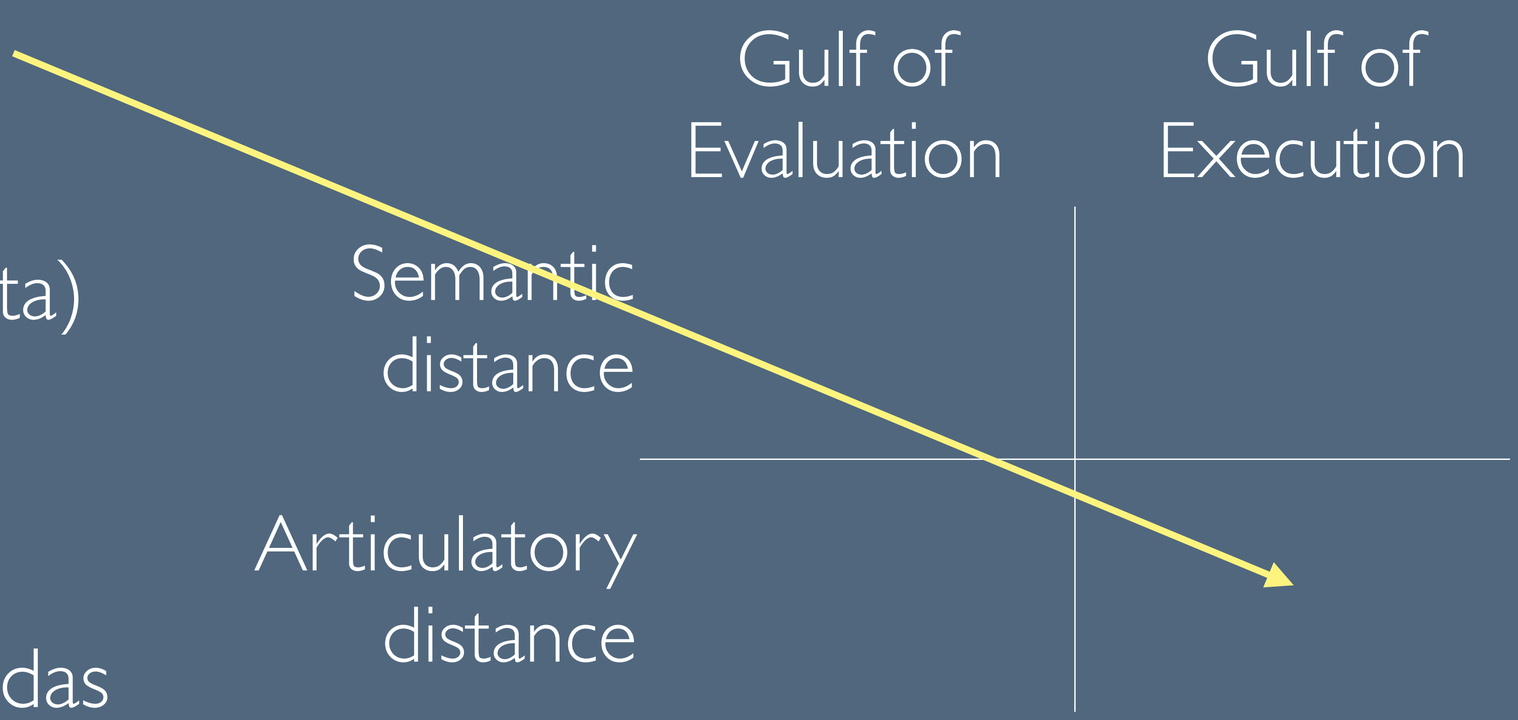

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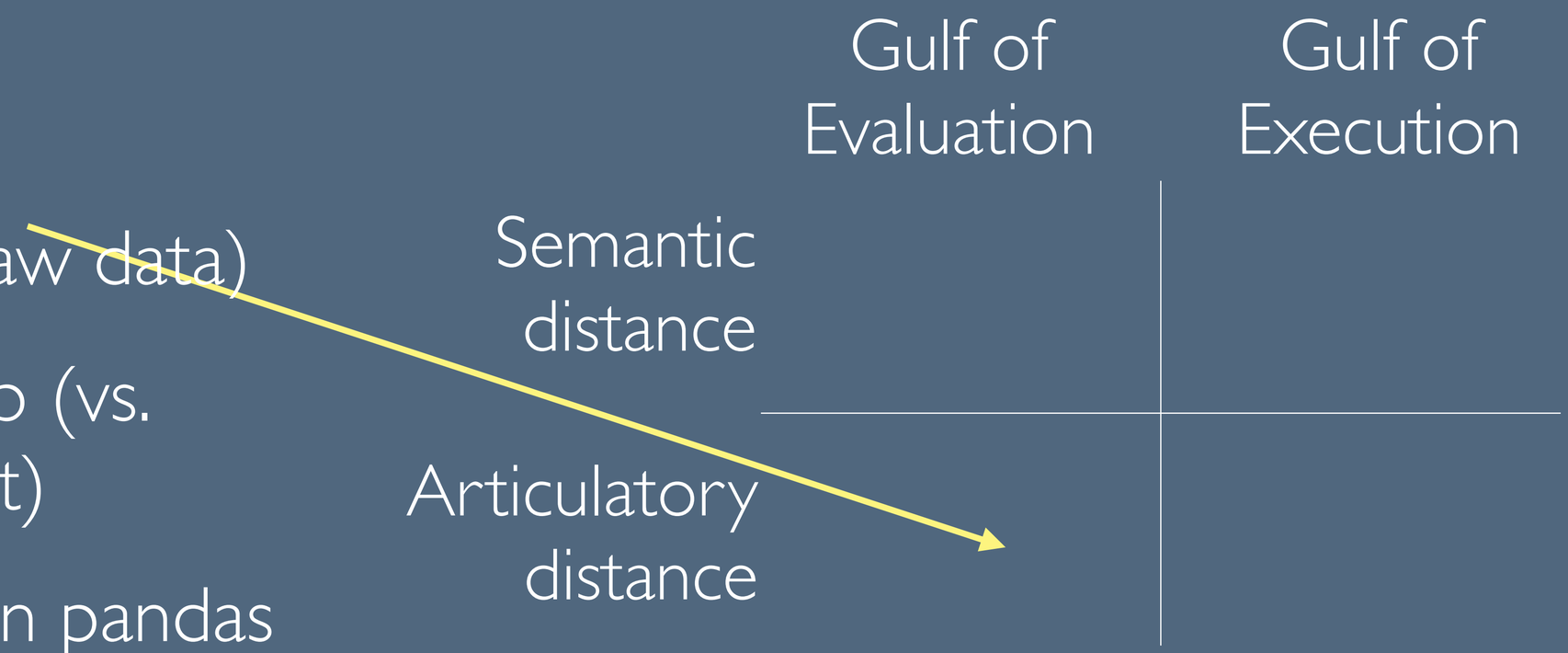

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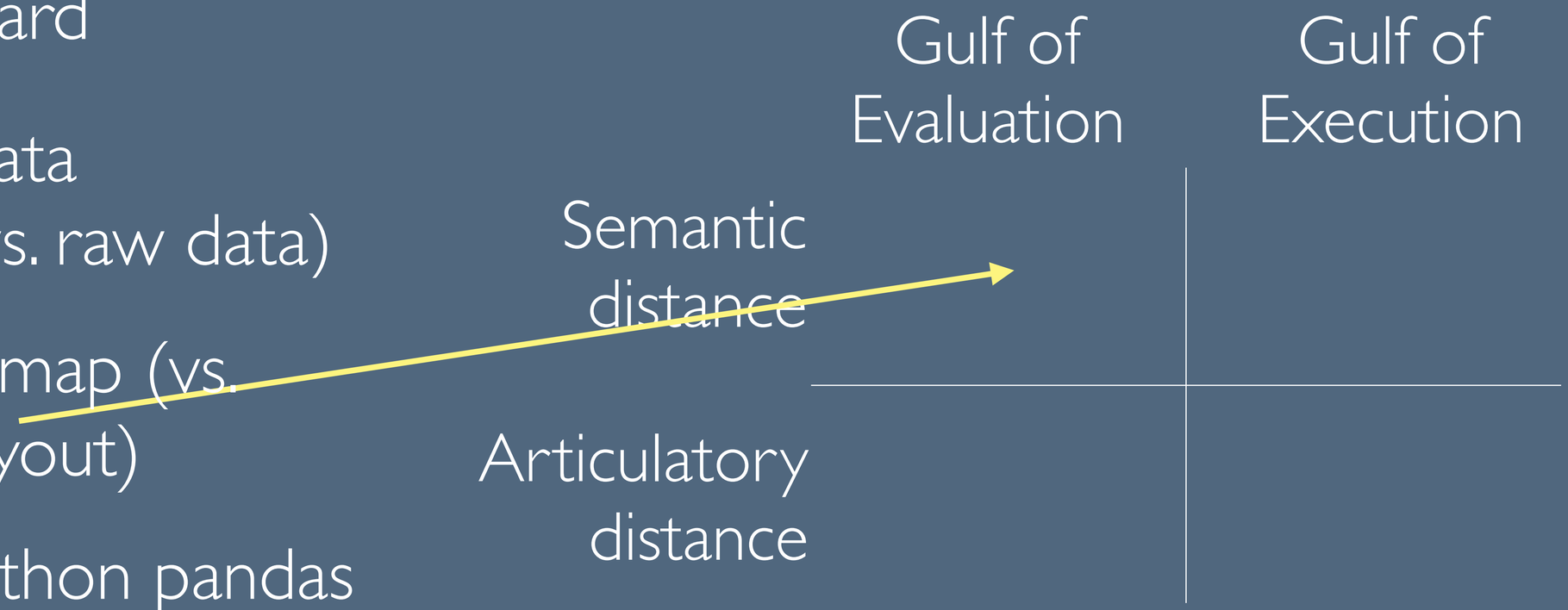

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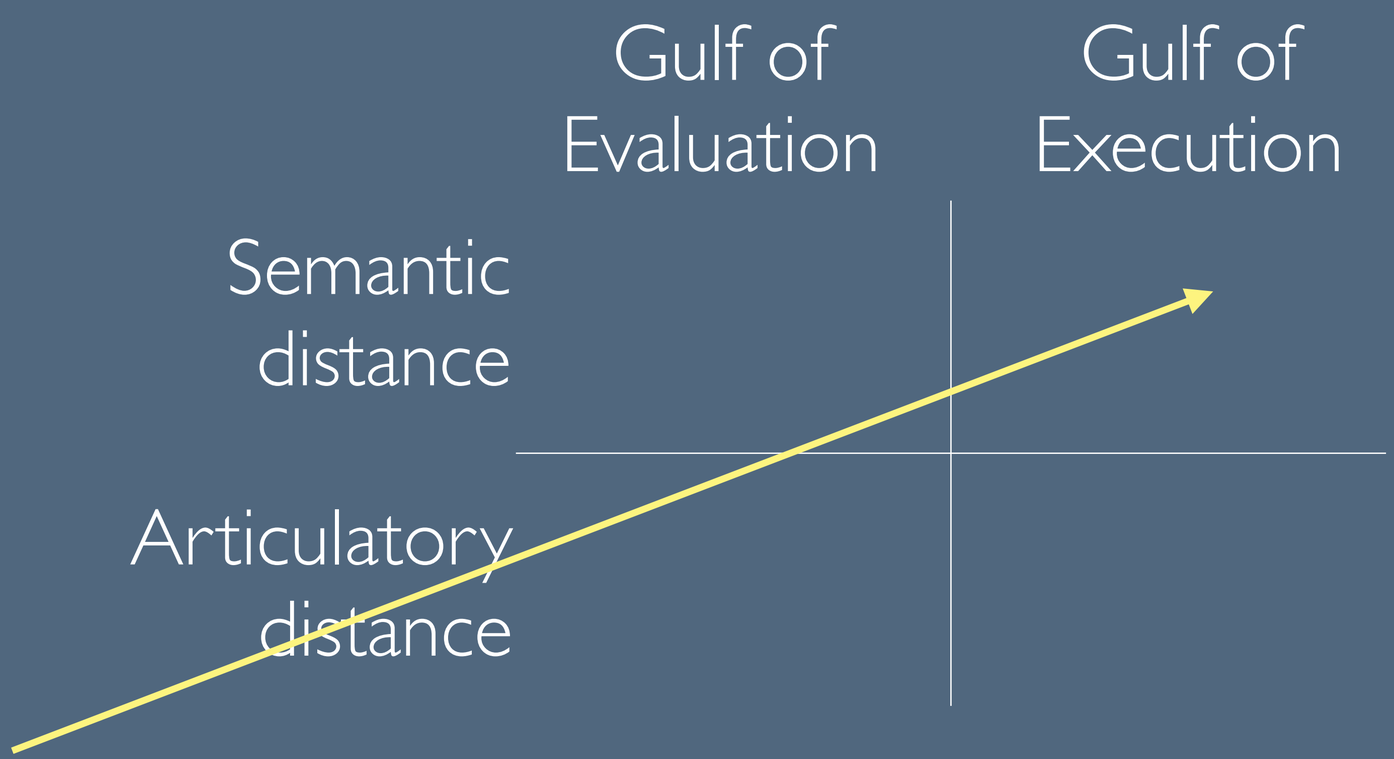
London Tube map (vs. geographic layout)

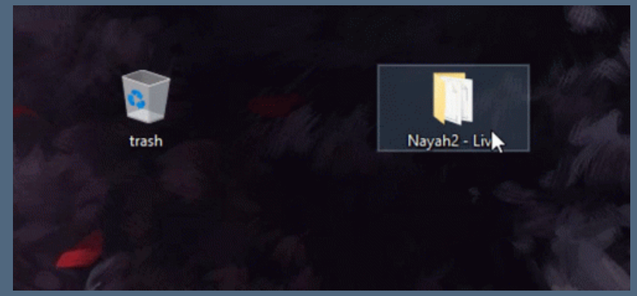
DSLs (e.g., Python pandas `df.groupby('column').mean()`)



Direct manipulation

[Hutchins, Hollan and Norman 1985]

Modern GUIs often adopt a metaphor of acting directly on the object of interest: **direct manipulation**. This reduces the gulfs.



Rather than scripts and code input, we act directly on the object
Rather than interpreting code output, the object itself has changed.

So, rather than aiming for "natural" interfaces, we should ask: **which gulf is this interface closing, and how?**

Gulfs in practice

1. **Gestural interaction**: the gulf of execution may remain wide, because either the semantic distance is large (Which gesture am I supposed to use again?), or the articulatory distance is large (It's hard to get the gesture recognized.)

2. **AI+HCI tools**: even if end-user tools reduce the gulf of execution, they may not reduce the gulf of evaluation (How do I interpret the AI errors?) or the next gulf of execution (How do I tweak the prev. result?)

Summary

Cognitive accounts can explain many challenges we face in design:

- **Design fixation:** unnecessarily focusing on a subset of the design space
- **Analogical transfer:** what do we see as related inspiration?

They can also help us be precise about how to improve design:

- **Gulfs of execution & evaluation:** what needs to be reduced?

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