

# Cognitive Mechanisms That Power Learning And Creativity

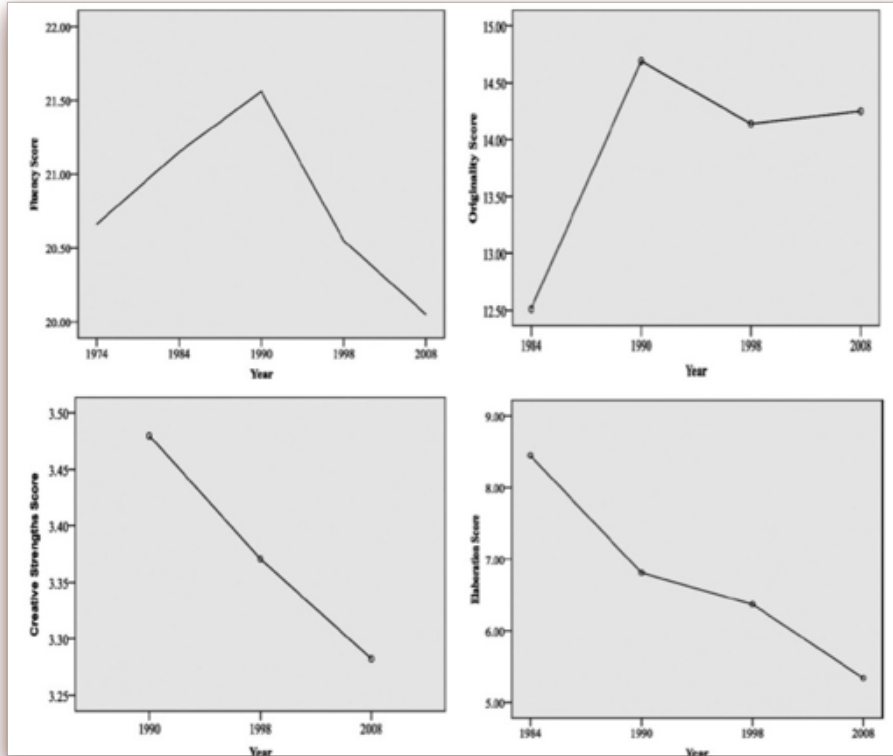
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Collaborators: Aishni Parab, Sumit Gulwani

# My Story





Creativity scores have been declining since 1990

- Decline across all measures
  - Originality, Fluency, Elaboration, Creative Strengths
- Trend accelerated in recent years

Source: Kyung Hee Kim, "The Creativity Crisis: The Decrease in Creative Thinking Scores on the Torrance Tests of Creative Thinking", Creativity Research Journal, 2011

## Outline

- What is creativity?
- Techniques for enhancing creativity
- Teaching AI to be more creative
- Can we leverage AI to make *humans* more creative?



# What is Creativity?



Idea Creativity

Vs.



Artistic Creativity

**Creativity = Originality x Appropriateness**

# Example

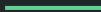


Simba:

- Likes to sit on the couch
- Rings the patio door bell to go outside

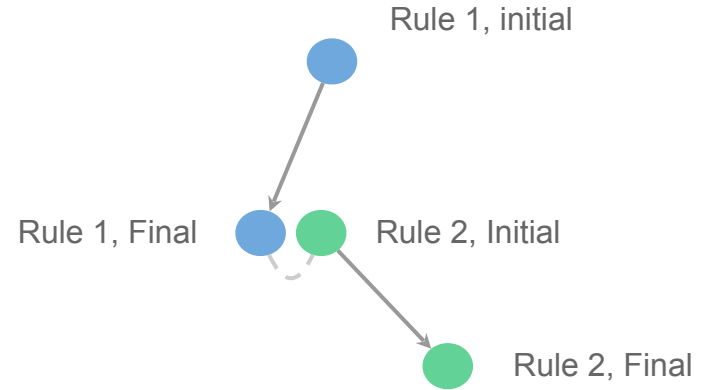
One day the couch was occupied.

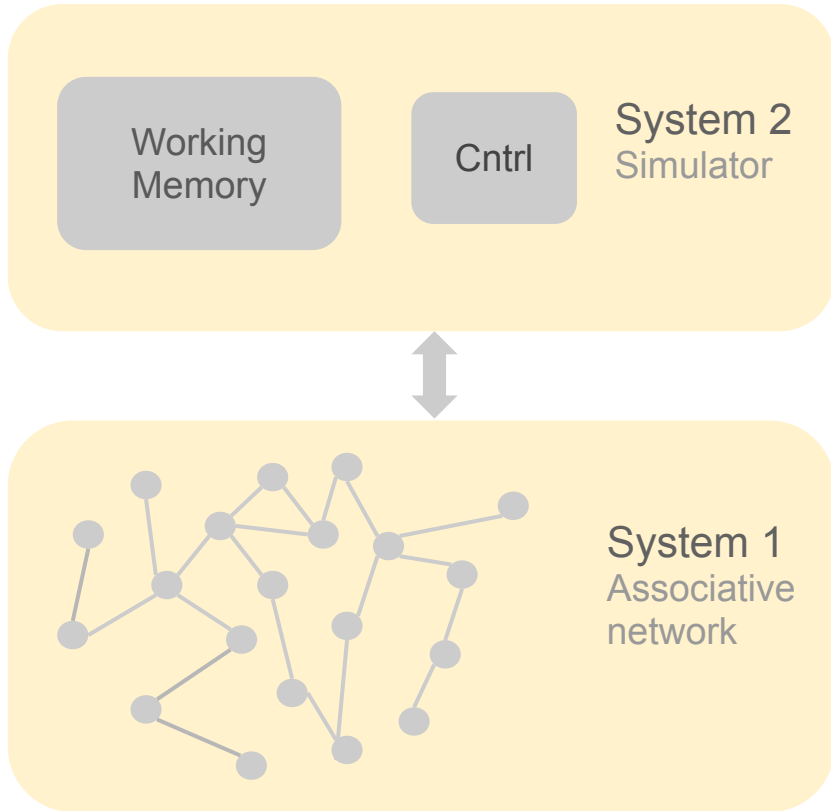
How did he solve the problem?



# Creativity Example

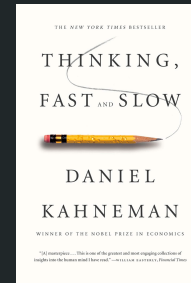
- Displayed a ***novel*** way to ***solve a problem***
- Simple rules in his brain
  - *Ring bell -> Someone gets up*
  - *Someone gets up -> He jumps on couch*





## Higher levels of creativity by managing System 1

- “Prompt Engineering” for System 1



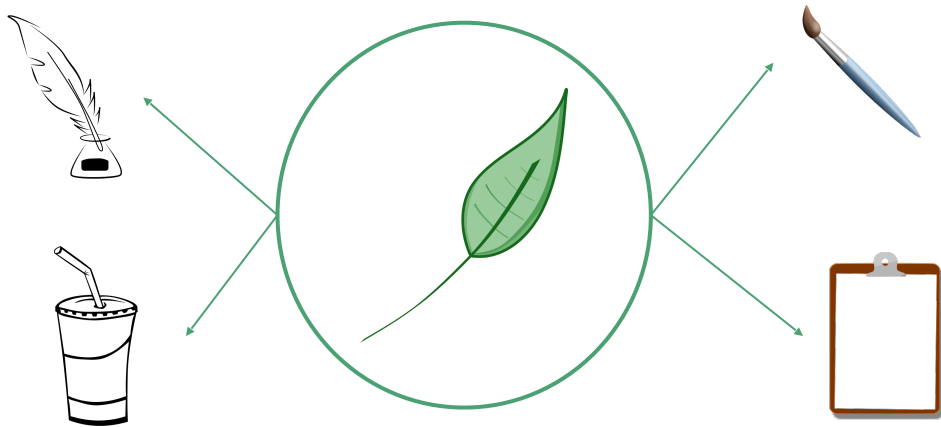
# Quick Experiment

## Outline

- What is creativity?
- Techniques for enhancing creativity
  - These techniques lead to > 2x more creative ideas
- Teaching AI to be more creative
- Can we leverage AI to make *humans* more creative?

# Technique 1: Divergent Thinking

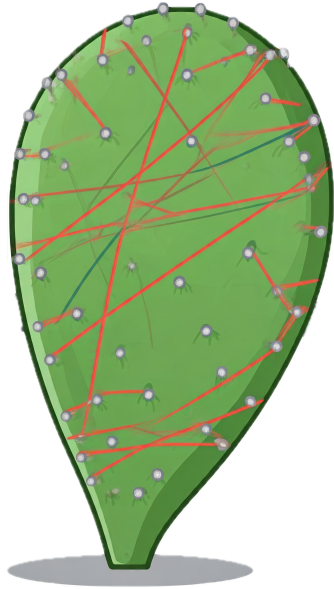
Typical Challenge: **How many different ways can you use a *leaf*?**



Solution by a 4th grader

=> Ideas show low flexibility (fewer categories of ideas)

# Divergent Thinking



*Image Credit: Gemini*

“Think of all the different kinds of leaves you have seen before”

Newer ideas start to surface:

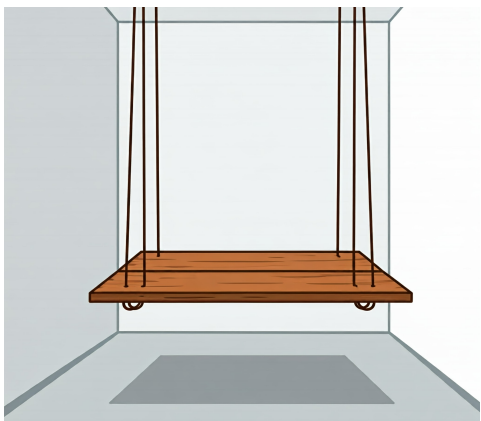
- Cactus leaf to make string art
- Banana leaf to make window shades
- Pine needles to make holes in paper



## Technique 2: Reversing Assumptions

**Identify an assumption and reverse it.**

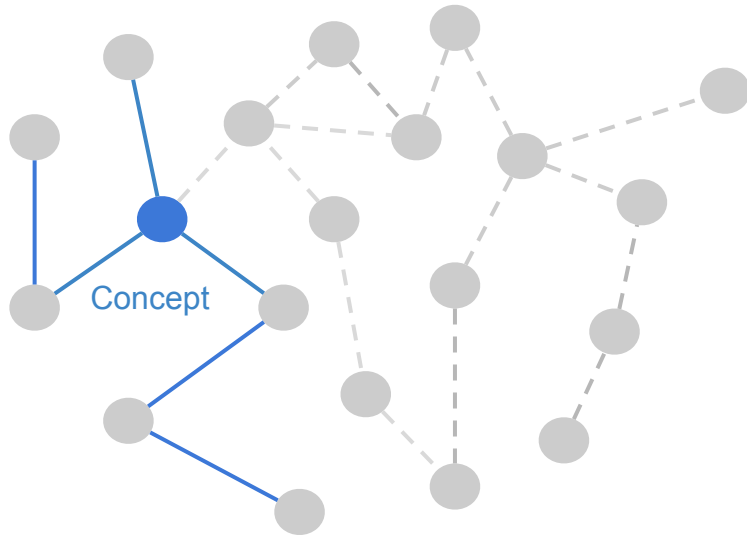
For example, tables have 4 legs => *What if tables didn't have legs?*



*Image Credit: Gemini*

<= Solution by a middle school student

# Reversing Assumptions



When you reverse an assumption, you eliminate a whole set of pathways that relied on that assumption.



# Reversing Assumptions

Younger students have a hard time *identifying* an assumption

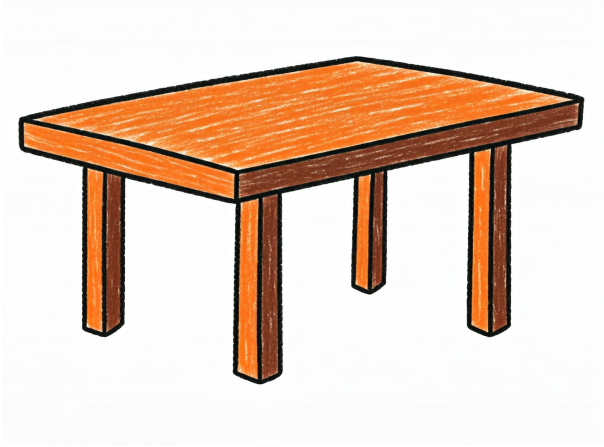


Image Credit: Gemini

Asking students to draw makes it easier to surface assumptions

- Brain stores the most common (prototypical) representations of objects
- Drawing seems to make it easier

## Technique 3: Associative Thinking

**Challenge is to combine unrelated objects into a something new.**

For example: What invention can you make by combining a **mug** and a **ball**?

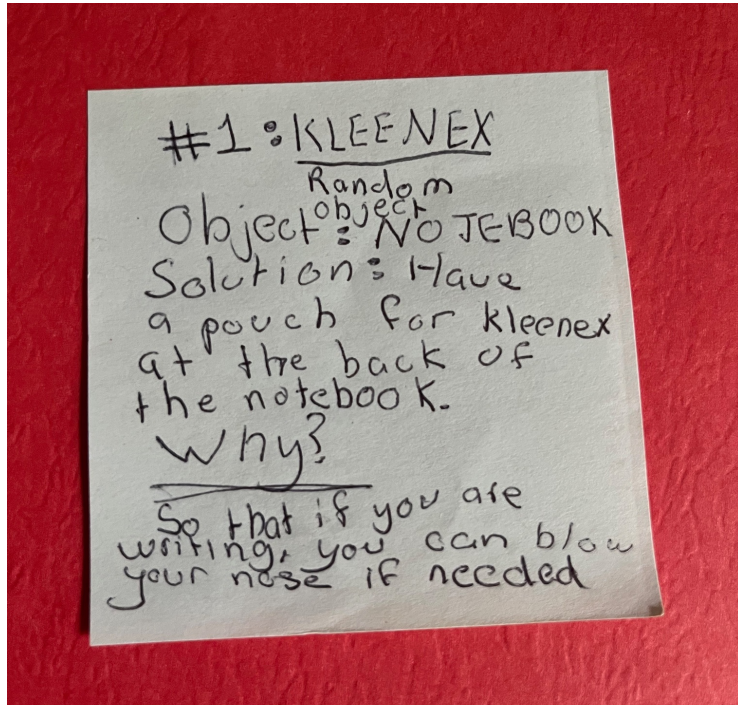


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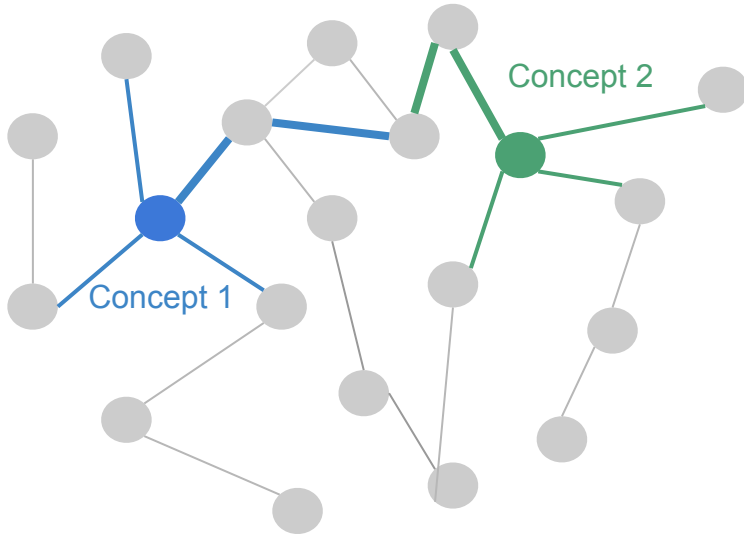
= **Inflatable Mug**

# Random Association Example

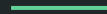


- Younger students tend to combine objects literally
- Asking them to use attributes improves sophistication of responses

# Random Association



- As neurons related to each concept start firing, the brain finds connections
- Discover new pathways



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# Improving Creativity of LLMs Using Associative Thinking

- LLMs capture associations between concepts based on frequency of occurrence of words
  - Limited form of associative network
- Hypothesis
  - **Associative thinking techniques that improve human creativity will also improve LLM creativity.**



# Domains

## Product Design

Pencil, Paint Brush,  
Scissors,  
Comb,  
Coffee Table

## Story Telling

Cinderella,  
Snow White and the  
Seven Dwarfs,  
Sleeping Beauty,  
Rapunzel,  
Aladdin

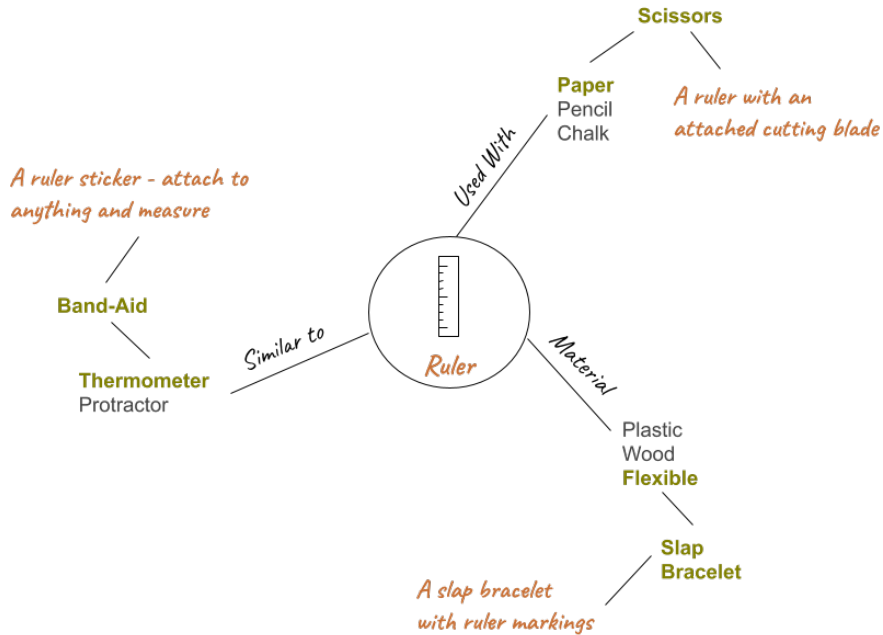
## Marketing

Coffee shop,  
Yoga Studio,  
Stationery Store,  
Vintage Record Store,  
Candy Store

# Methodology

- Ask LLM to suggest novel idea (*control*), by incorporating a random element (*random association*)
- Tip: Use an attribute of the random object instead of the object directly
- Product design scenario used an additional experiment: *One-hop*
- Six human annotators evaluated responses (except originality for product design)

# One-hop

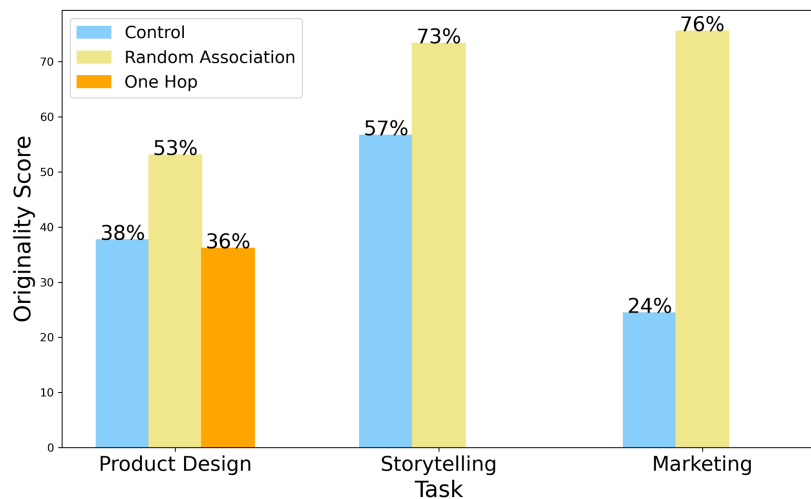


Instead of completely random,  
combine concepts by hopping  
over one node

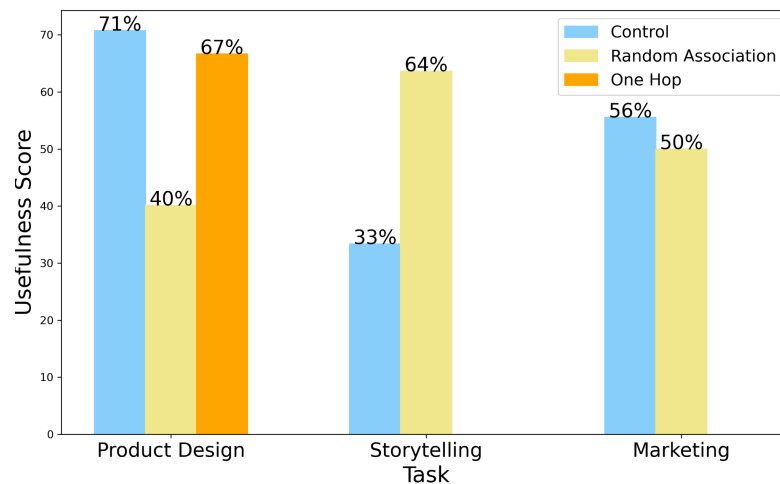
=> Reduces incongruity

Source: Ludden et al, "Surprise and Humor in Product Design," Humor, vol 25, no. 3, 2012

# Results



Originality of responses went up for all three domains.



v-GPT4 is strong in storytelling. Marketing was close to control while product domain produced less useful ideas.

# Product Design Example

Goal: Design an innovative pencil



## **Screw-Inspired Pencil:**

This innovative design features a spiral groove running along the body of the pencil, resembling a **screw**. This groove allows the user to 'screw' the pencil into a special holder or a notebook cover, ensuring that it is securely fastened and always within reach.

# Marketing Example

Goal: Design a creative marketing flyer for a stationery store



Control



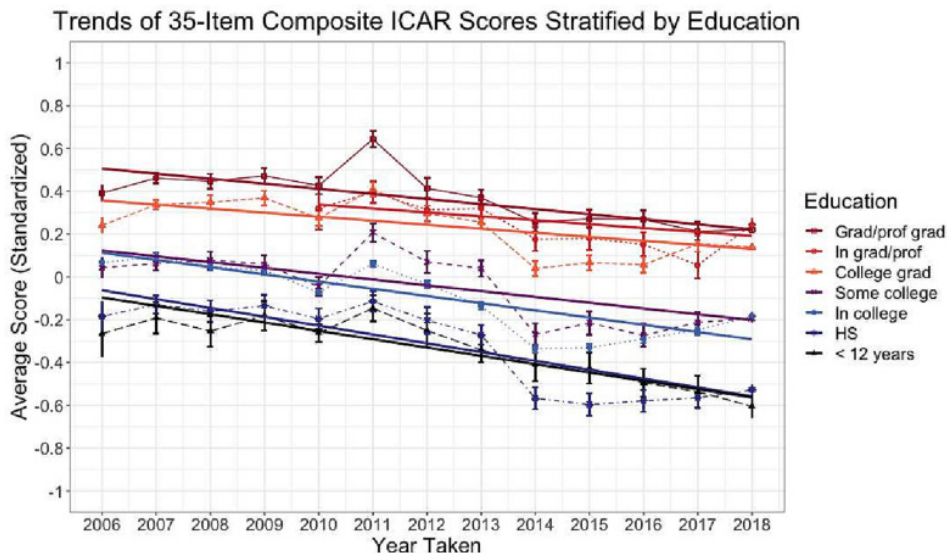
Association: Vase

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# Decline In Thinking Skills

- Reverse Flynn Effect
  - IQ was increasing every decade and started declining in 2000s
  - Visual-spatial skills increased
  - All other domains including verbal reasoning, letter and number series
- Technology is a contributing factor
  - Visual media improved visual-spatial skills but others declined



Source: Dworak et al., “Looking for Flynn effects in a recent online U.S. Adult Sample: Examining shifts within the SAPA project”, *Intelligence*, 98, 2023



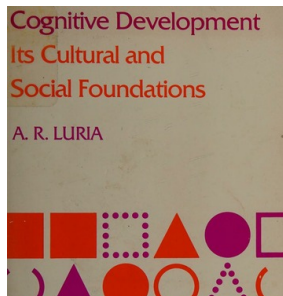
Q: There are no camels in Germany; the city of B is in Germany; are there camels there or not?

A: *I don't know, I have never seen German villages. If B is a large city, there should be camels there.*

Q: But what if there aren't any in all of Germany?

A: *If B is a village, there is probably no room for camels.*

An interview with rural, isolated Russians in 1920s



## Logical reasoning is a recently acquired skill

- Infant and toddler toys teach sorting, categorization etc.
- Schools build “comparing and contrasting” skills with more abstract concepts

# Generative AI Can Harm Learning

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<sup>4</sup>Budapest British International School

## Short-term improvement

- 48% (base), 127% (tutor)

## Long-term harm

- 17% (base)
-

# Tools for Thought

Better thinking through AI



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## Vision

Much AI research focuses on solving specific tasks for people – generating content or automating processes. While such systems may be powerful, there are risks that this approach may bring to human cognition. They may impact the way people think and therefore learn, build skills, and grow expertise for example.

The Tools for Thought (T4T) team aims to put human cognition at the heart of our systems. Our goal is to help researchers and systems builders to focus not just on automation, but on *augmentation*, imagining how AI might help people to *think better*. To this end, we research the impact of AI on aspects of cognition and use this to design and build systems that support individual and collective intentionality, enhance skills in critical thinking, and develop cultures of creativity and experimentation.

- Focusing on solving specific tasks carries risk to human cognition
- We need AI to help people *think better*

# Future Ideas

- LLMs that integrate creative thinking techniques that *prompt humans* to think in different ways
  - Brainstorming or thinking buddy
- AI in education
  - Teacher assistant to create personalized lesson plans that incorporate different thinking styles
  - Teacher assistant to create multi-disciplinary projects to connect topics in different subjects that students are learning
  - Improve hints to allow “desirable difficulties” that tie to better learning outcomes

Thank you to my collaborators:

Aishni Parab, Sumit Gulwani

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