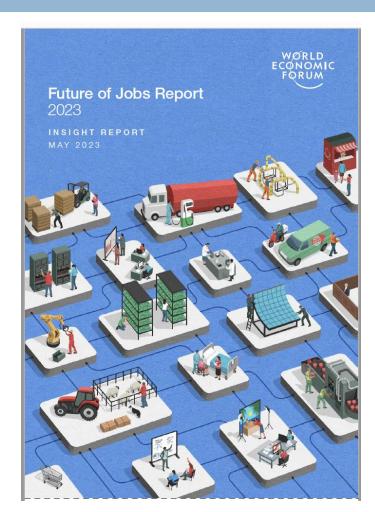




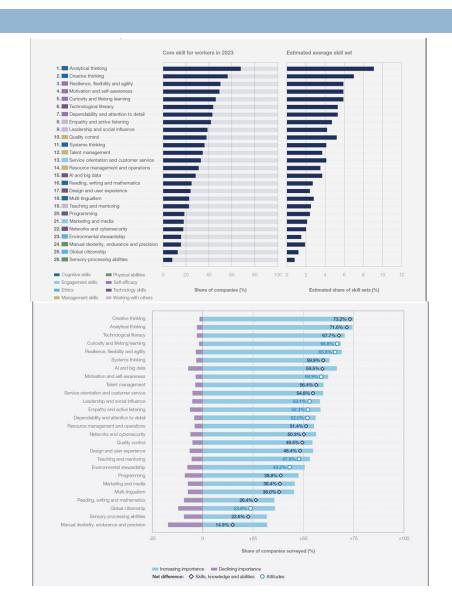
# HUMAN CREATIVITY IN THE AGE OF THE MACHINE

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Faculty of Data and Decision Sciences
Technion — Israel Institute of Technology

# Why does it matter?



https://www.weforum.org/publications/ the-future-of-jobs-report-2023/



Press

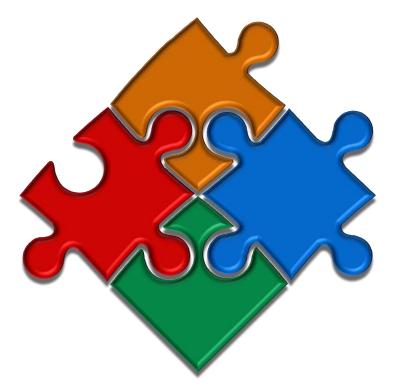
The Provironment In?

which@reativity@ccurs

# The creativity metaverse

## Person

What makes each person creative at an individual level



## Process

This dognitive and neural mechanisms that realize creative ideation

Product
The actual reative artifact

# Creativity research evolution



Creative cognition (mid '90's)

Creativity neuroscience (early 2000's)

Computational creativity (mid 2010's)

# Measuring Creativity

- How can creativity be quantified?
- Human creativity
  judgements are
  subjective, and can be
  unreliable



Can machines objectively assess human creativity?

## Link to tools

Forward Flow https://osf.io/7p5mt/ DSI https://osf.io/ath2s/ OCSAI https://openscoring.du.edu/scoringllm **AUDRA** https://osf.io/kqn9v/ Bloom complexity model https://osf.io/823ak/ Creative problem solving https://osf.io/45veq/?view\_only=9fcb23a2564b4190a4ceb1f2f1707129 CAP https://cap.ist.psu.edu/

# Key take-home message

Focus on openended tasks that facilitate divergent thinking



## Who is more creative?





1. What does it mean?

2. How can we tell?

## Creative Al?

## Putting GPT-3's Creativity to the (Alternative Uses) Test

How AI outperforms humans at creative idea generation

The Creative Al-Land: Exploring new forms of creativity

**Introducing Aspects of Creativity in Automatic Poetry Generation** 

Assessing Novelty, Feasibility, and Value of Creative Ideas with an Unsupervised Approach

**Pushing GPT's Creativity to Its Limits: Alternative Uses and Torrance Tests** 

The originality of machines: AI takes the Torrance Test

The current state of artificial intelligence generative language models is more creative than humans on divergent thinking tasks

# The most common in-lab creativity task





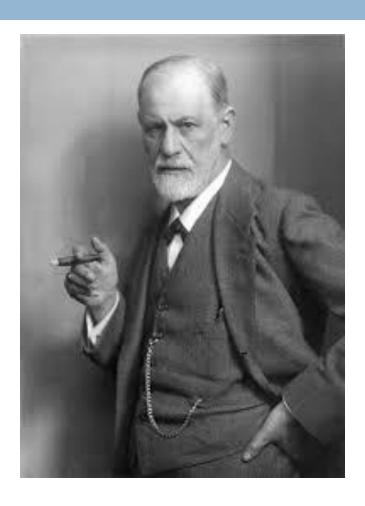




## Chain free association task



12

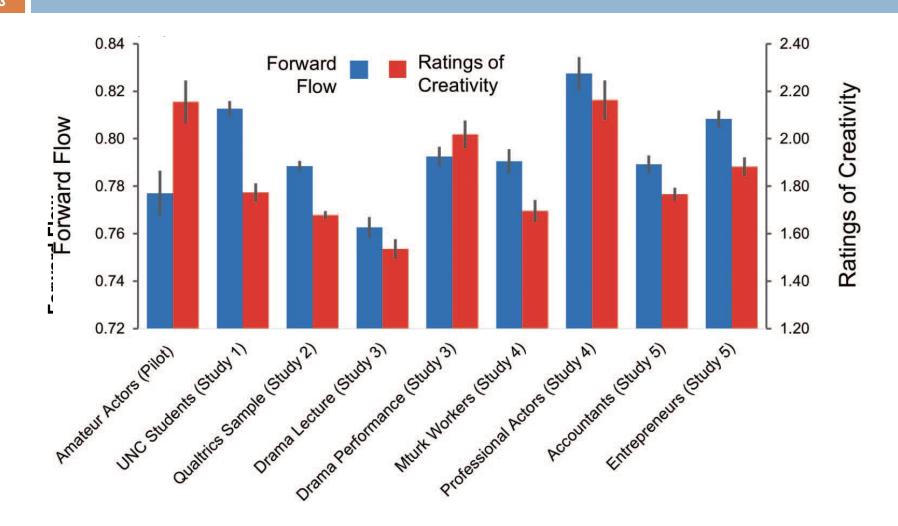


Write down the next word that follows in your mind from the previous word	
Press TAB after each word. Continue when all text boxes are complete.	

#### Your starting word is 'Table'

## Forward flow





## Divergent association task



Home Take the test About FAQ Team

# The Divergent Association Task measures verbal creativity in under 4 minutes

It involves thinking of 10 unrelated words. People who are more creative tend to think of words with greater "distances" between them, showing more divergent thinking.

Take the test (2 to 4 minutes)

We recommend that you <u>take the test</u> before you <u>learn more about it</u>. You can also read a <u>CNN article</u> on the task or read our <u>open-access manuscript</u> in *Proceedings of the National Academy of Sciences*.



## Deconstructing the process

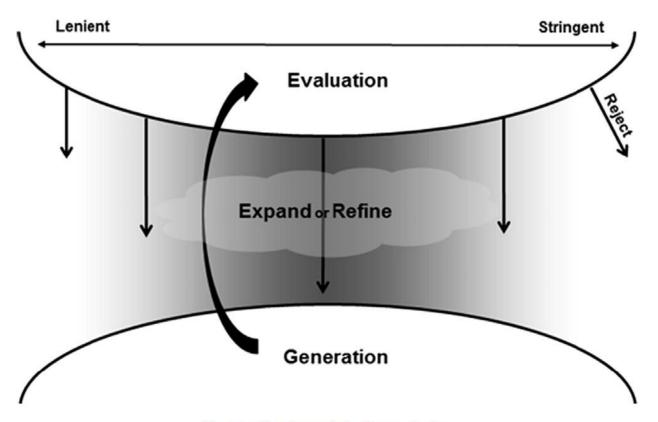
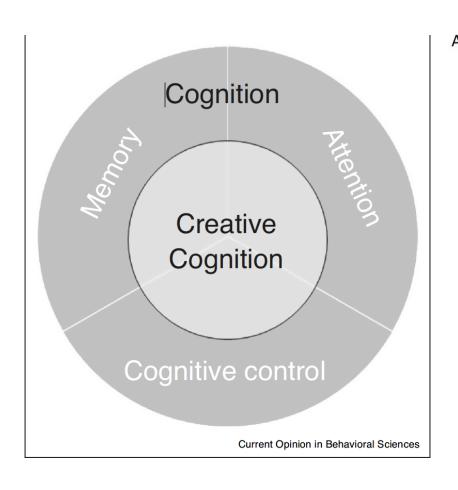


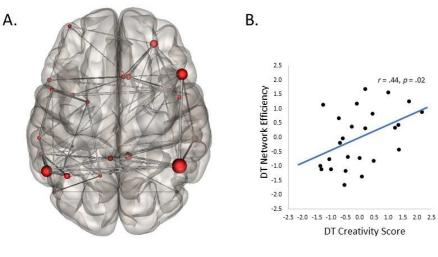
Fig. 1. Dual-model of creativity.

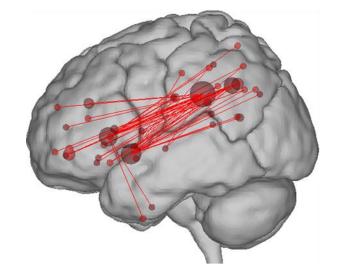
## Creativity neuroscience



# A neuro-cognitive model







# Unpacking the role of knowledge in creative ideation

nature reviews psychology https://doi.org/10.1038/s44159-023-00158-z Check for updates The role of memory in creative ideation Mathias Benedek @ 1 ≥ Roger E. Beaty @ 2, Daniel L. Schacter @ 3.4 & Yoed N. Kenett @ 5 Abstract Sections Creativity reflects the remarkable human capacity to produce novel and Introduction effective ideas. Empirical work suggests that creative ideas do not just Creative ideation and memory emerge out of nowhere but typically result from goal-directed memory processes. Specifically, creative ideation is supported by controlled retrieval, involves semantic and episodic memory, builds on processes Memory across stages used in memory construction and differentially recruits memory at different stages in the creative process. In this Perspective, we propose a memory in creative ideation (MemiC) framework that describes how creative ideas arise across four distinguishable stages of memory search. candidate idea construction, novelty evaluation and effectiveness evaluation. We discuss evidence supporting the contribution of semantic and episodic memory to each stage of creative ideation. The MemiC framework overcomes the shortcomings of previous creativity theories by accounting for the controlled, dynamic involvement of different memory systems across separable ideation stages and offers a clear agenda for future creativity research. Department of Psychology, University of Graz, Graz, Austria, 2Department of Psychology, Pennsylvania State University, University Park, PA, USA. 3Department of Psychology, Harvard University, Cambridge, MA, USA. 4Center for Brain Science, Harvard University, Cambridge, MA, USA. Faculty of Data and Decision Sciences, Technion -

#### Trends in **Cognitive Sciences**

Review

### Associative thinking at the core of creativity

Roger E. Beaty 601.\* and Yoed N. Kenett 602

Creativity has long been thought to involve associative processes in memory: connecting concepts to form ideas, inventions, and artworks. However, associative thinking has been difficult to study due to limitations in modeling memory structure and retrieval processes. Recent advances in computational models of semantic memory allow researchers to examine how people navigate a semantic space of concepts when forming associations, revealing key search strategies associated with creativity. Here, we synthesize cognitive, computational, and neuroscience research on creativity and associative thinking. This Review highlights distinctions between free- and goal-directed association, illustrates the role of associative thinking in the arts, and links associative thinking to brain systems supporting both semantic and episodic memory - offering a new perspective on a longstanding creativity theory.

#### Revisiting the role of associative thinking in creativity

What is the first word that comes to mind when you think of creativity? Some people may associate creativity with art: others with imagination, novelty, or expression. This exercise illustrates the phenomenon of association - how one concept links to others in memory, and how people vary in the associations they make [1]. Creative thinking has long been conceptualized as involving an associative process over memory, where concepts are combined to form new and effective ideas [2-6]. However, associative thinking has been historically challenging to study, due in part to methodological limitations in modeling memory and the retrieval processes operating on it. Prior studies have relied on simple measures of association, such as counting the total number of associations produced (i.e., the product of associative thinking) - obscuring the process of associative thinking and limiting our understanding of its role in creativity.

Recent advances in the computational modeling of semantic memory - the vast database of concepts, and the relationships between them [7] - have begun to overcome these limitations, yielding new insights into associative thinking and its contribution to creativity. In particular, distributional semantic models (see Glossary) provide powerful tools for quantifying semantic distance, allowing researchers to quantitatively measure how far people travel in a se mantic space (or network) of concepts when searching memory. Cognitive and neuroimaging studies of associative thinking have yielded additional insights, from disentangling spontaneous/free association versus controlled/goal-directed association, to demonstrating the role of associative thinking in the arts and sciences, to linking associative thinking to brain systems implicated in creative thought.

In this Review, we integrate cognitive, computational, and neuroscience research on creativity and associative thinking. We operationalize creativity as a cognitive process involving the generation of new and effective ideas [8], while recognizing that creativity is complex, multifaceted, and often domain specific. We focus on the role of associative thinking as a general mechanism driving the early stage of idea generation. We therefore view creative thinking as a form of high-level cognition - a product of lower-level cognitive systems, including cognitive control, attention, and memory [9, 10].

Creativity involves associative thinking linking concepts from memory. Computational models of semantic memory allow researchers to quantify associative thinking as movement through a semantic space of concepts.

Associative thinking reflects a search process operating on a semantic memory network structure. Highly creative people travel further in semantic space, gories, and make larger leaps between

Creativity involves both free associations in which concepts are spontaneously connected, and goal-directed associa-

Free association is relevant for artistic creativity, implicating domain-general cognitive abilities in domain-specific creative expertise.

Neuroscience evidence indicates associative thinking engages brain regions involved in both semantic and episodic

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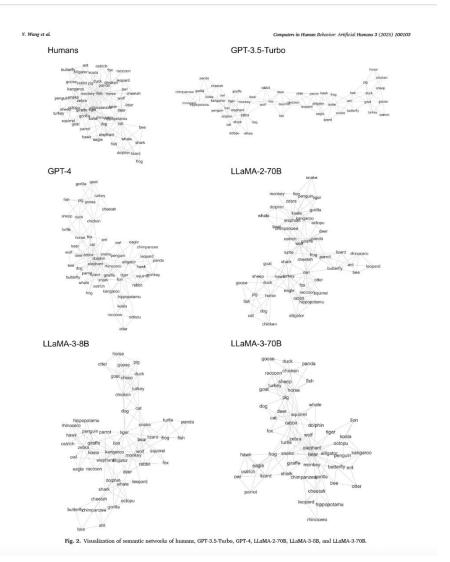
Trends in Cognitive Sciences, July 2023, Vol. 27, No. 7 https://doi.org/10.1016/j.tics.2023.04.004 671

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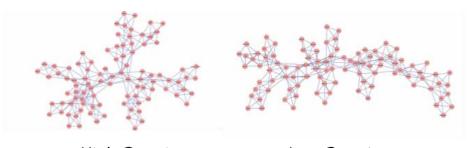
Israel Institute of Technology, Haifa, Israel. Me-mail: mathias.benedek@uni-graz.at

# Memory structure & creativity





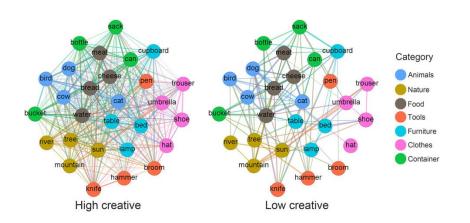
## Groups



**High Creative** Individuals

Low Creative Individuals

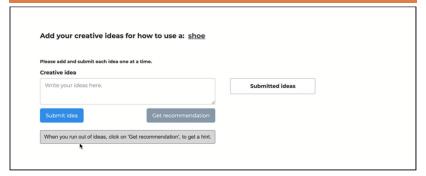
## Individuals

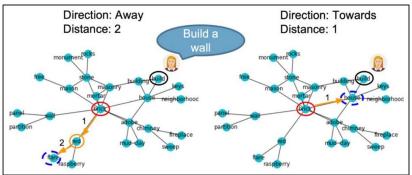


# Memory search & creativity



## **Associative Creativity Sparker**





Paper:



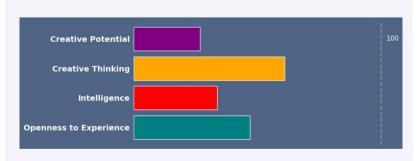
Tool:



## **High-level Cognitive Prediction**



#### **Model Predictions**



Tool:



## A creativity human vs. Al arm wrestle



2023 Volume 2 Article 13 https://doi.org/10.59453/ll.v2.13

## Is artificial intelligence more creative than humans? ChatGPT and the Divergent Association Task

#### **David Cropley**

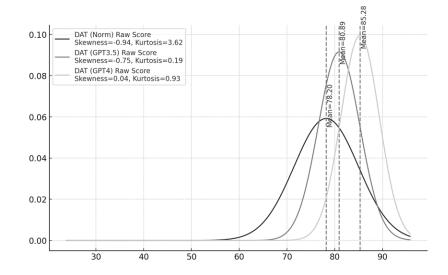
Centre for Change and Complexity in Learning, University of South Australia

A fundamental premise of the future of work is that AI will replace people in many cognitive and physical tasks, leaving creativity as a core, human 21st century skill. However, the recent launch of generative AI (especially ChatGPT) has seen many claims that AI is creative. If true, then the foundation of future human work, and education, is under threat. To examine claims of AI creativity, this research applied a test of verbal divergent thinking – the Divergent Association Task – to two versions of ChatGPT (GPT3.5 and GPT4). The results are reported and compared to a large human baseline. While both forms of ChatGPT show a capacity for verbal divergent production that exceeds human means, a range of factors call into question the "creativity" of generative AI.

Keywords: artificial intelligence, ChatGPT, creativity, divergent thinking

Corresponding author: David Cropley, david.cropley@unisa.edu.au

Recommended citation: Cropley, D. (2023). Is artificial intelligence more creative than humans? ChatGPT and the divergent association task. Learning Letters, 2, Article 13. https://doi.org/10.59453/ll.v2.13



## Humans $\rightarrow$ GPT3.5 $\rightarrow$ GPT4

- Higher (quantitative) originality
- Lower variability

## We're different, we're the same

#### We're Different, We're the Same: Creative Homogeneity Across LLMs

EMILY WENGER\*, Duke University

YOED KENETT, Technion - Israel Institute of Technology

Numerous powerful large language models (LLMs) are now available for use as writing support tools, idea generators, and beyond. Although these LLMs are marketed as helpful creative assistants, several works have shown that using an LLM as a creative partner results in a narrower set of creative outputs. However, these studies only consider the effects of interacting with a single LLM, begging the question of whether such narrowed creativity stems from using a particular LLM—which arguably has a limited range of outputs—or from using LLMs in general as creative assistants. To study this question, we elicit creative responses from humans and a broad set of LLMs using standardized creativity tests and compare the population-level diversity of responses. We find that LLM responses are much more similar to other LLM responses than human responses are to each other, even after controlling for response structure and other key variables. This finding of significant homogeneity in creative outputs across the LLMs we evaluate adds a new dimension to the ongoing conversation about creativity and LLMs. If today's LLMs behave similarly, using them as a creative partners—regardless of the model used—may drive all users towards a limited set of 'creative' outputs.

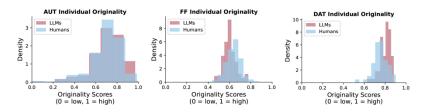
#### 1 INTRODUCTION

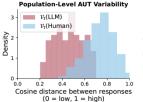
Large language models (LLMs) have moved out of research labs and into our everyday lives. Given their advanced abilities to generate text and respond to prompts, LLMs are often marketed as creativity support tools that allow users to write drafts, edit documents, and generate novel ideas with ease [2, 4, 20, 21]. Consumers have responded eagerly to these suggestions. According to a 2024 survey by Adobe, over half of Americans have used generative AI tools like LLMs as creative partners for brainstorming, drafting written content, creating images, or writing code. An overwhelming majority of LLM users surveyed believe these models will help them be more creative [39].

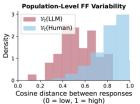
While appealing, outsourcing our creative thinking to LLMs could have unintended consequences and demands further scrutiny. For example, recent work has unearthed complications around the use of LLMs as creativity support tools. Researchers found that LLM-aided creative outputs look individually creative but are often quite similar to other LLM-aided outputs. Such "homogeneity" in LLM-aided creative outputs has been observed in a variety of settings, from creative writing to online survey responses to research idea generation and beyond [7, 16, 37, 43, 53].

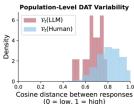
While concerning, these works typically only look at a single LLM and it's effect on downstream creative content. In a prototypical example, Doshi and Hauser [16] compared the individual and collective creativity of two groups of writers—humans alone and humans aided by ChatGPT—and found that stories produced by the ChatGPT-aided group were more homogeneous. Related work from Moon, Green, and Kushlev [37] compared college essays written by humans and GPT models and found that LLM-authored essays contributed fewer new ideas and were more homogeneous than human-authored essays. However, such work begs the question: does the observed homogeneity occur because limited arange of outputs, causing the homogeneity. Perhaps if writers all used different LLMs, creativity would be restored.

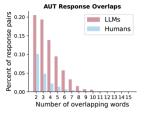
Recent work studying feature space alignment in LLMs suggests otherwise. There is a long line of work measuring feature space similarity in machine learning models, since this is believed to indicate overall model similarity [8, 31, 33, 34, 46]. Some initial work has applied these techniques to large-scale LLMs and found evidence of "feature university in these models [26, 29, 32]. We postulate that such feature uspace alignment in LLMs may result in homogeneous

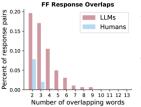


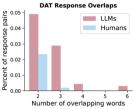












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# Variablity is key!



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#### THEORETICAL NOTE

#### An Entropy Modulation Theory of Creative Exploration

Thomas T. Hills<sup>1</sup> and Yoed N. Kenett<sup>2</sup>

<sup>1</sup> Department of Psychology, University of Warwick

<sup>2</sup> Faculty of Data and Decision Sciences, Technion—Israel Institute of Technology

Compared to individuals who are rated as less creative, higher creative individuals tend to produce ideas more quickly and with more novelty—what we call faster-and-further phenomenology. This has traditionally been explained either as supporting an associative theory—based on differences in the structure of cognitive representations—or as supporting an executive theory—based on the principle that higher creative individuals utilize cognitive control to navigate their cognitive representations differently. Though extensive research demonstrates evidence of differences in semantic structure, structural explanations are limited in their ability to formally explain faster-and-further phenomenology. At the same time, executive abilities also correlate with creativity, but formal process models explaining how they contribute to faster-and-further phenomenology are lacking. Here, we introduce entropy modulation theory which integrates structure and process-based creativity accounts. Relying on a broader of evidence, entropy modulation of entropy during cognitive search (e.g., memory retrieval). With retrieval targets racing to reach an activation threshold, activation magnitude and variance both independently enhance the entropy of target retrieval and increase retrieval speed, reproducing the faster-and-further phenomenology. Thus, apparent differences in semantic structure can be produced via an entropy modulating retrieval process, which tunes cognitive entropy to mediate cognitive flexibility and the exploration—resploitation trade-off.

Keywords: creativity, executive function, network science, entropy

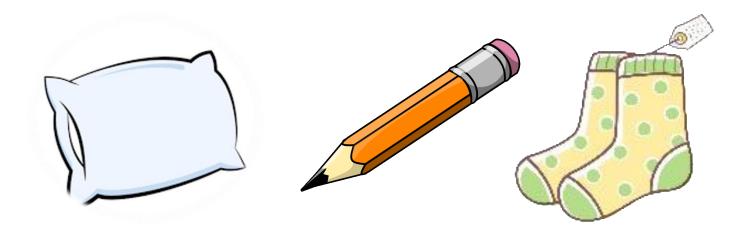


r Psychological Association or one of its allied publisher





## The alternative questions task



What are all the creative questions you can ask about these objects?





# Our question asking research...

- 1. The role of asking complex questions in creative thinking
- 2. Automatic scoring of question complexity
- 3. The role of question asking in open-ended and close-ended problems
- 4. Question asking and prompt engineering
- 5. The neural correlates of question asking
- 6. Question asking ad aging
- Question asking training
- Social aspects of question asking
- Questions asked by journalists in interviews
- 10.

## Question asking & prompt engineering





## The Art of Creative Inquiry—From Question Asking to Prompt Engineering

#### ABSTRACT

As artificial intelligence and natural language processing methods rapidly develop, communication plays a pivotal role in every-day interactions. In this theoretical paper, we explore the overlap and commonalities between question-asking and prompt engineering. While seemingly distinct, these processes share a common foundation in essential skills like creativity, critical thinking, and cognitive flexibility. We contend that prompt engineering, the art of crating cues for language models, and question-asking, the skill of formulating inquiries, form a symbiotic relationship. Delving into question complexity through Bloom's taxonomy and diverse types of questions, we propose strategies for not only efficient but also engaging prompt design. Our theoretical contribution emphasizes the dynamic role of creativity in both processes, offering intriguing perspectives on human-machine interactions and advancing our understanding of language models and communication skills.

Keywords: prompt engineering, question asking, creativity, large language models.

Co-creativity is generally defined as multiple parties contributing to a creative process in a blended manner (Davis, 2013). Although in some creative situations tasks can be completed through a distribution of labor, the results in this case only represent the sum of each individual's contribution. Co-creativity goes beyond this labor allocation model and allows individuals to contribute in a collaborative and synthetic manner. Thus, ideas can be fused, combined, and added onto each other such that they originate from a myriad of personalities and team members' motivations (Candy & Edmonds, 2002). It can then yield more creative solutions than if each party completed each task separately and added them together, that is, the sum is greater than its parts. Co-creativity is becoming especially relevant now in the age of generative artificial intelligence (Al) where highly advanced generative Al can now begin to match humans in performance on creativity tests (Hubert, Awa, & Zabelina, 2024) and has the potential to augment the creativity of every knowledge worker on Earth (Rafner et al., 2023; Rafner, Besty, Kaufman, Lubart, & Sheson, 2023). Although autonomously operating Al agents will certainly continue to amaze us, such technologies in the hands of creative experts can offer potentially endless avenues of innovative abilities.

An integral part of successful co-creativity is good communication (Kantosalo & Takala, 2020). Decades of human-computer interaction research on conversational interfaces suggest that people's perceived utility of these technologies can be shaped by how these agents communicate and clarify their capabilities (Liao & Vaughan, 2023). Contemporary AI models such as ChatGPT and GPT-4 (Achiam et al., 2024) are becoming increasingly popular tools in many linguistic human-computer interactions. These large language models (LIM) are a class of deep neural networks that undergo pre-training on large amounts of text data, for the purpose of understanding and generating language, and can then aid in machine translation, question answering, automatic summarization, and other language tasks (Desai, Sharma, & Saha, 2023). Thus, in the ever-evolving landscape of AI and natural language processing, the art of clearly communicating, which includes how the models introduce and clarify their capabilities, take initiatives, repair errors, and respond to chat requests, stands at the forefront of potential groundbreaking advancements in the way we interact with these systems.

While question-asking stands as a fundamental process of shaping communications between humans (Huang, Yeomans, Brooks, Minson, & Gino, 2017), prompt engineering has emerged as a key pillar in shaping the interactions between humans and language models (Meskő, 2023; White et al., 2023).

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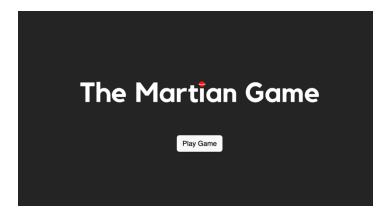
TABLE 2. Example Prompts and Key Terms for LLMs Corresponding to Bloom Taxonomy Levels.

Bloom's Taxonomy Level	Bloom Level Description	Key Terms	Example Prompt
Remembering	Retrieving relevant knowledge	Define, describe, label, list, identify	"List all the planets in the Solar System in order from the Sun"
Understanding	Determining the meaning of instructional messages, including oral, written, and graphic communication	Contrast, generalize, outline, explain, represent	"Explain the significance of the water cycle to Earth's climate system"
Applying	Carrying out or using a procedure in a given situation	Apply, examine, interpret, transfer, predict, organize	"Given a dataset of weather conditions, predict whether it will rain tomorrow using a simple linear regression model"
Analyzing	Breaking material into its constituent parts and detecting how the parts relate to one another	Discriminate, compare, differentiate, structure	"Compare and contrast the economic impacts of renewable vs. non-renewable energy sources"
Evaluating	Making judgments based on criteria and standards	Conclude, appraise, assess, justify, judge, review	"Assess the effectiveness of the recent public health campaign on reducing smoking rates among teenagers"
Creating	Putting elements together to form a novel, coherent whole	Compose, design, compile, synthesize, rewrite, formulate	"Design a sustainable city plan that incorporates green energy, efficient public transport, and supports local biodiversity"

# Developing open- and closed-ended question asking games









Play Me!



Play Me!



## So - is there still a 'human edge'?



- Variability
- Knowledge
- Idea evaluation
- Context
- Dynamics
- Complexity
- Flexibility
- III-defined problem solving
- Associative thinking
- Analogical thinking

# (complex) Questions?



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