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FACULTY OF DATA
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MAKING SENSE OF IT

CREATIVE THINKING

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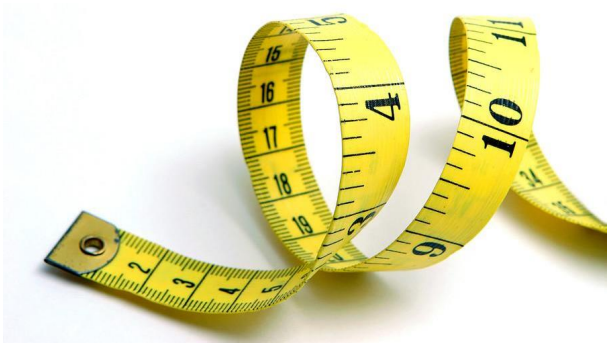
December 15th, 2024

Today -

Knowledge



Assessment

Questions

Creativity and learning 1/2

Making connections: Creativity supports learning through associative thinking

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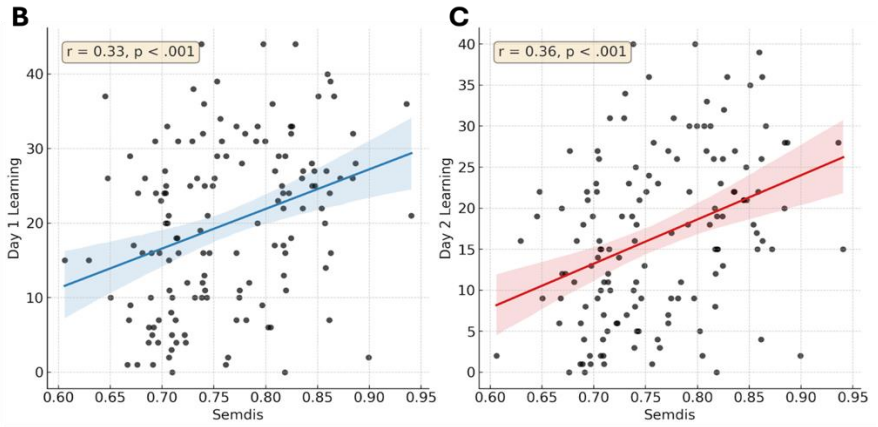
- Learning Efficiency Test
  - learning Lithuanian-English word pairs
- associative thinking
  - verb generation task



Creativity and learning 2/2

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Examining the relations between semantic memory structure and creativity in second language

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ABSTRACT

Creativity is related to a higher flexible semantic memory structure, which could explain greater fluency of ideas. Extensive research has identified a positive connection between creativity and bi-/multilingualism mainly in contexts where two languages or more concur in daily communicative interactions. Yet, creativity has received scant attention in regard to L2 (second or foreign language) acquisition that mainly takes place in classroom situations. The scarce research points to a positive relationship between creativity and L2 fluency – understood as the number of words produced. We apply computational network science analysis and Forward Flow methods to examine lexical organization patterns of a low creativity (LC) and high creativity (HC) group of 12th grade Spanish English as a Foreign Language (EFL) learners. The participants completed two fluency tasks, where they generated animal names in their L2, and also L1 – used here as a control measure. EFL proficiency was controlled. Our analyses revealed that the HC individuals were more fluent in L1 and L2, generated more remote responses, and exhibited a more flexible and efficiently structured semantic memory in both languages, with a greater effect of creativity in L2. Contrary to previous research, the L2 semantic memory network exhibited a less random organization. Differences in the L2 learning conditions are adduced as likely causes of this result.

1. Introduction

Recent neurocognitive research on creativity has pointed to differences in the semantic memory network structure of lower and higher creative individuals. These differences may explain, for example, greater associative fluency (i.e., the production of a greater number of responses), and more infrequent responses (i.e., responses based on more distant semantic connections), by higher creative individuals (Benedek & Neubauer, 2013; Benedek et al., 2020, Kenett & Faust, 2019). Furthermore, the semantic memory network structure of higher creative individuals has been found to be more flexible, or less structured, at different levels of lexical-semantic organization (Kenett et al., 2014; Kenett & Faust, 2019).

Bi/multi-lingualism has been generally found to be associated to creativity (e.g., Kharkhurin, 2011). This link might be explained by the frequently reported advantage of bilinguals in nonverbal executive control (Bialystok et al., 2012; Costa et al., 2008), which might facilitate creative cognition (Kharkhurin, 2017). The vast majority of studies on these variables have been mainly limited to high-proficient migrant individuals or contexts where two or more languages or more concur in everyday communicative interactions. Research is still embryonic regarding the connection between creativity and performance in second or foreign language (L2) in the case

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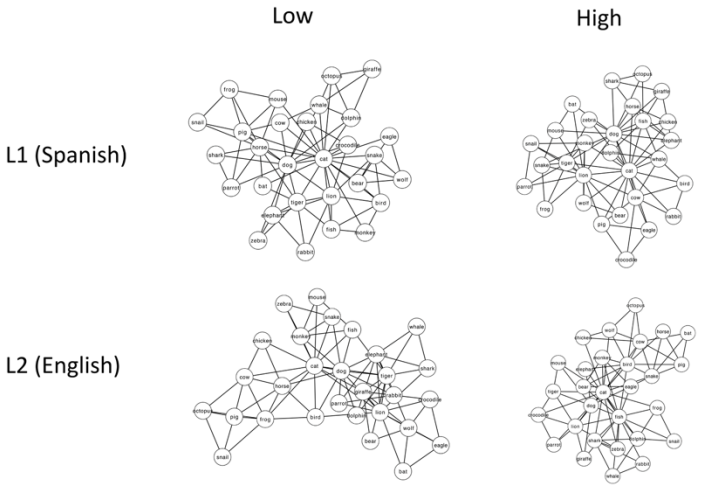
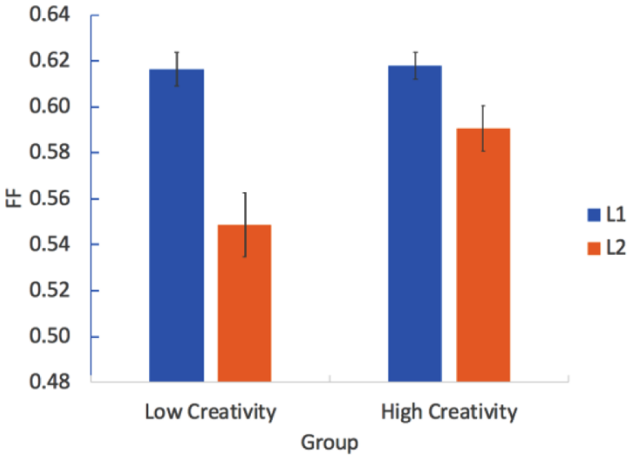




The role of knowledge in creativity

Research questions

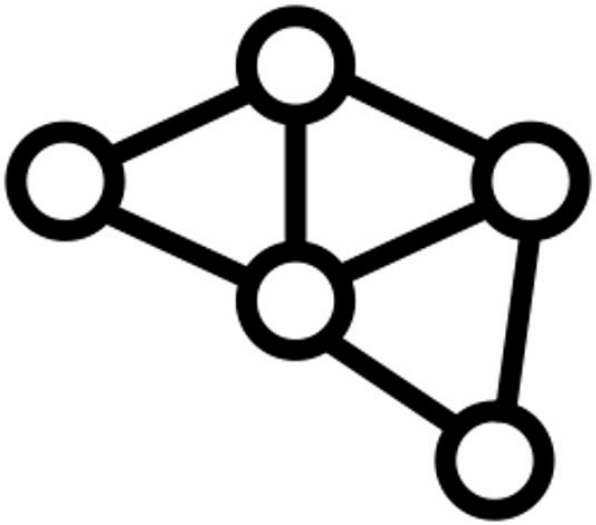
Cognitive

- What is the role of knowledge in creative thinking?
- What are the cognitive dynamics involved in the creative process?

Neural

- Is the creative brain "wired" differently?
- What are the neural dynamics involved in the creative process?

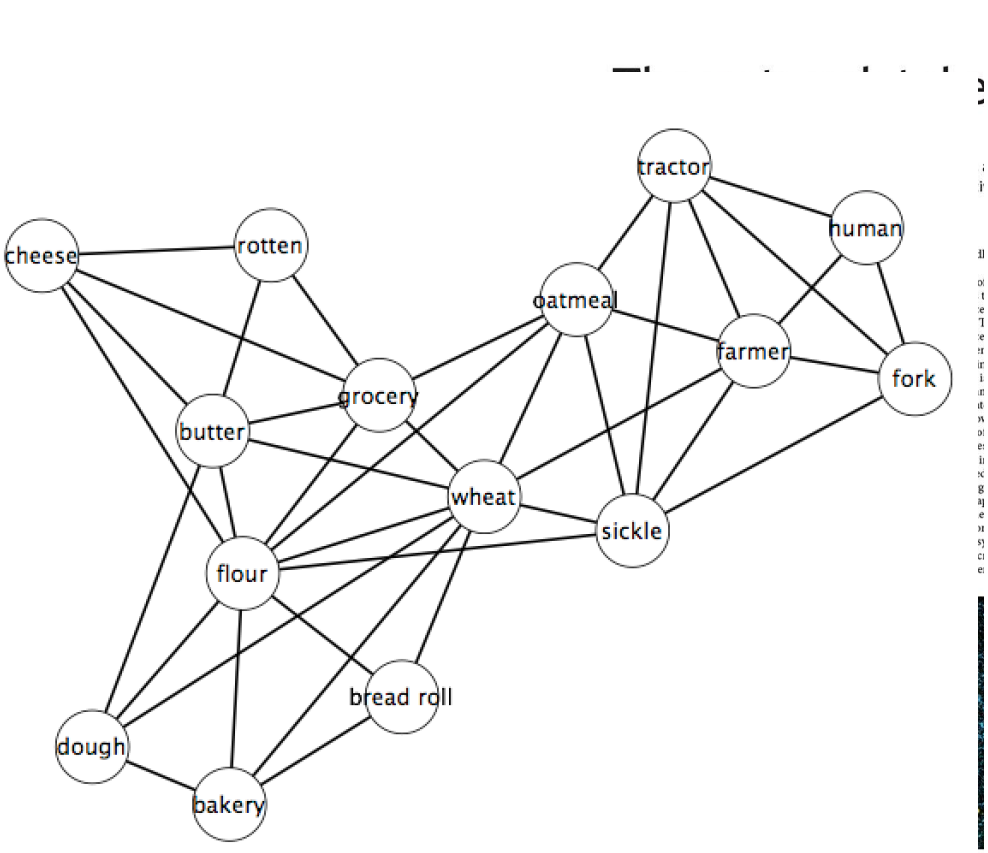
How do we search our memory?

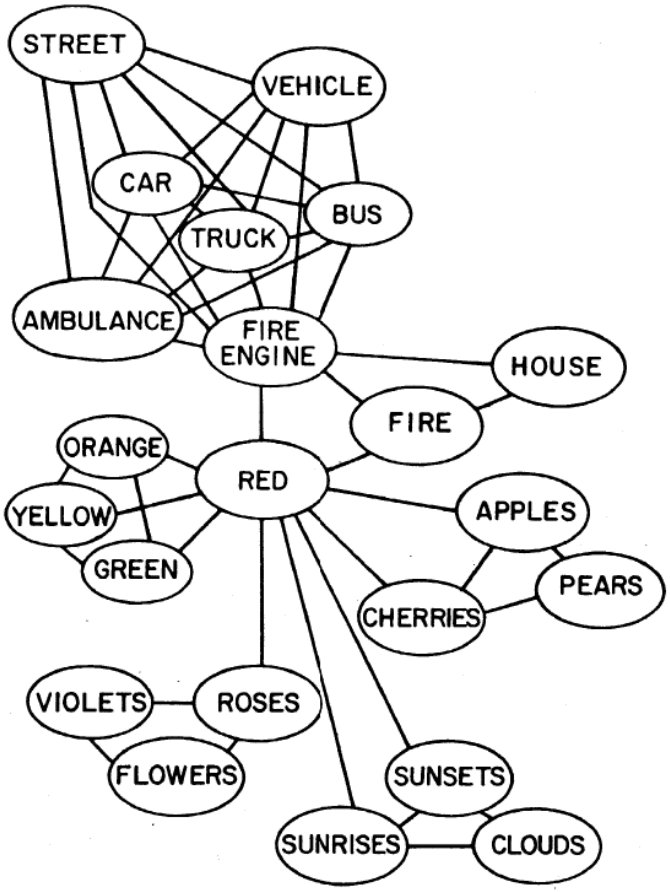


Map/space/
network

Vehicle/
process

Network Science





Network universe. A visualization of the first large-scale network explicitly mapped out
large-scale structure of real networks. The map was generated in 1999 and represents a
of the World Wide Web[9]; this map has led to the discovery of scale-free networks. Node
documents; links correspond to URLs. Visualization by Mauro Martino, Alec Pawling and Chaoming Song.

sensors and high-throughput technologies,

Kenett et al. (2011)

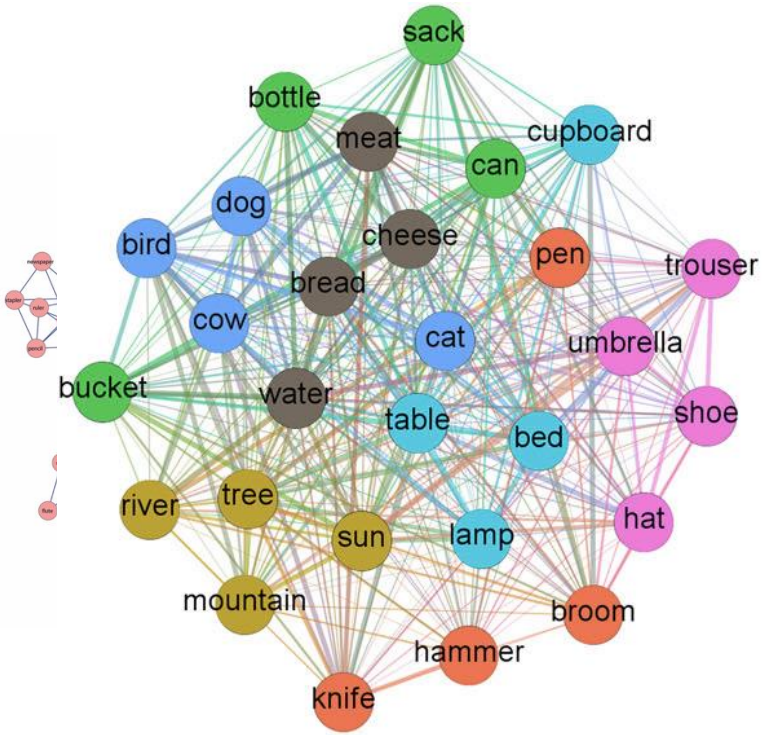
Collins and Loftus (1975)

The role of knowledge in creative thinking

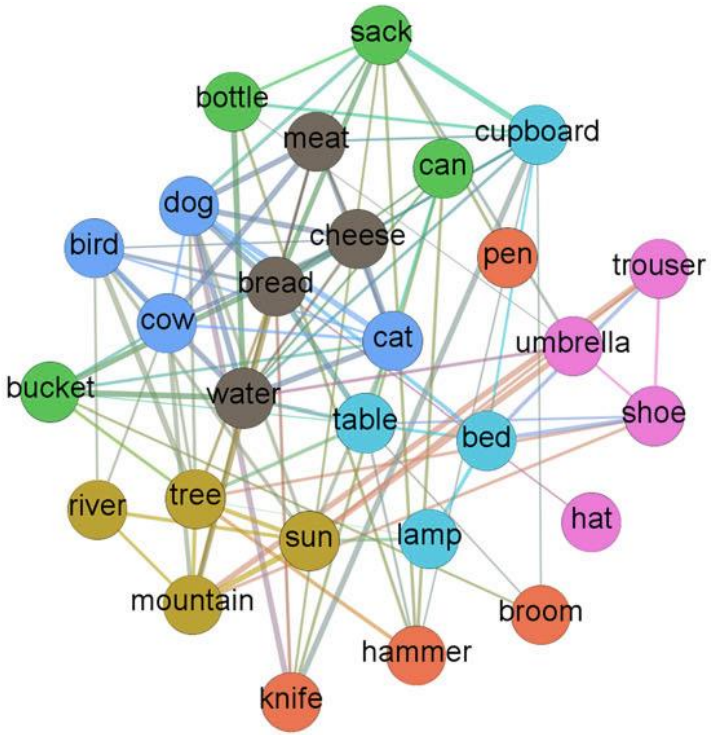
Structure

Dynamics

Young people



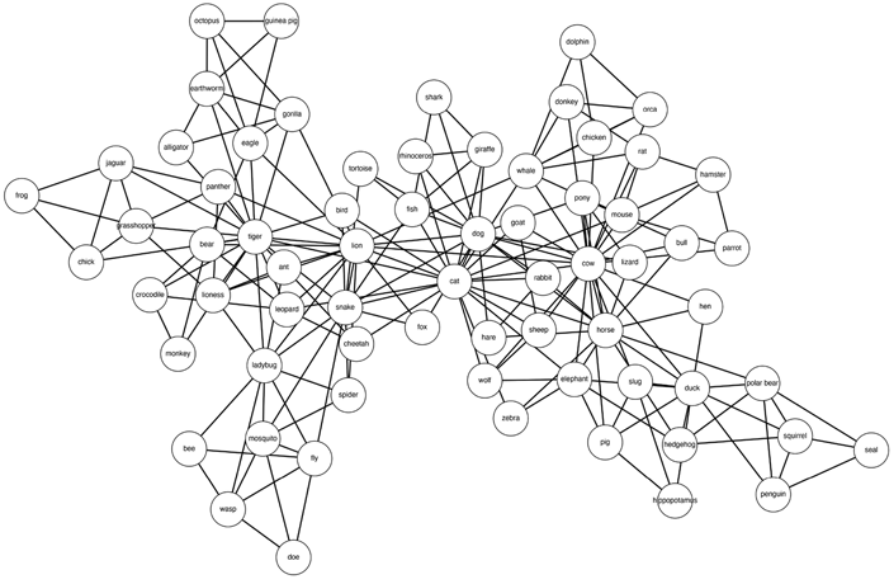
High creative



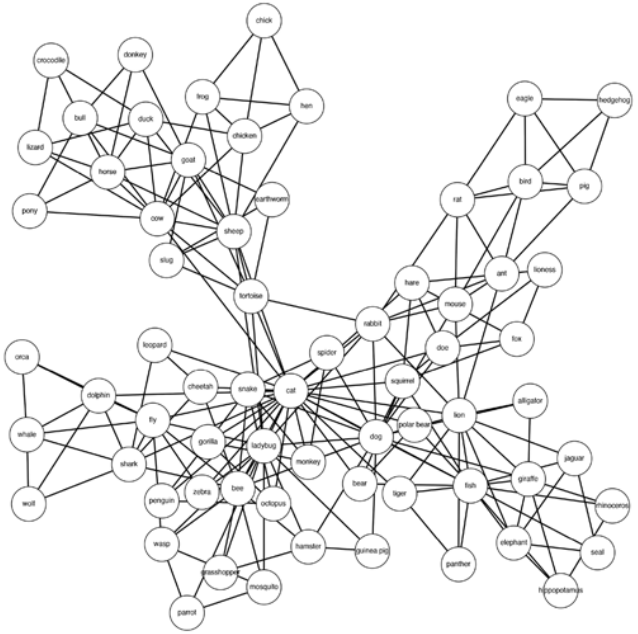
Low creative

Kenett et al. (2014). Thinking & Reasoning, 20(4), 407-427.

Children



Montessori



Traditional

Dénervau et al. (2021). *npj Science of Learning,* 6(1), 35.

Students

Journal of *Intelligence*

MDPI

Article

Mapping the Memory Structure of High-Knowledge Students: A Longitudinal Semantic Network Analysis

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Abstract: Standard learning assessments like multiple-choice questions measure what students know but not how their knowledge is organized. Recent advances in cognitive network science provide quantitative tools for modeling the structure of semantic memory, revealing key learning mechanisms. In two studies, we examined the semantic memory networks of undergraduate students enrolled in an introductory psychology course. In Study 1, we administered a cumulative multiple-choice test of psychology knowledge, the Intro Psych Test, at the end of the course. To estimate semantic memory networks, we administered two verbal fluency tasks: domain-specific fluency (naming psychology concepts) and domain-general fluency (naming animals). Based on their performance on the Intro Psych Test, we categorized students into a high-knowledge or low-knowledge group, and compared their semantic memory networks. Study 1 (N = 213) found that the high-knowledge group had semantic memory networks that were more clustered, with shorter distances between concepts—across both the domain-specific (psychology) and domain-general (animal) categories—compared to the low-knowledge group. In Study 2 (N = 145), we replicated and extended these findings in a longitudinal study, collecting data near the start and end of the semester. In addition to replicating Study 1, we found the semantic memory networks of high-knowledge students became more interconnected over time, across both domain-general and domain-specific categories. These findings suggest that successful learners show a distinct semantic memory organization—characterized by high connectivity and short path distances between concepts—highlighting the utility of cognitive network science for studying variation in student learning.

Keywords: cognitive network science; educational assessment; expertise; knowledge; semantic memory; undergraduate education

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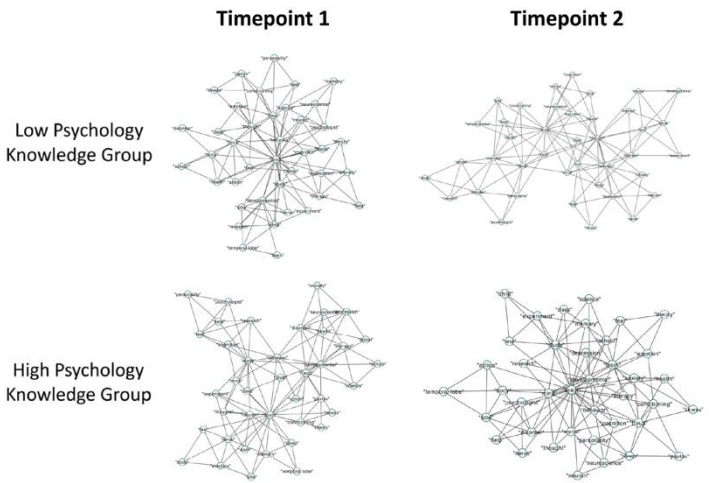
1. Introduction

Psychologists have long been interested in studying the relationship between learning and memory, a link that is of considerable importance for informing modern educational practices (Anderson 2000). To evaluate student learning, educators often employ assessments such as multiple-choice quizzes or short-answer questions (Becker and Watts 2001). Despite their popularity, such assessments can only evaluate what students know on a surface level. To provide a deeper understanding of student learning, researchers have recently employed methods from cognitive network science that can model (latent) knowledge structures. Network science quantifies the relationships between units in a complex system—such as words in a semantic memory network—providing powerful tools for understanding how students represent and retrieve knowledge to facilitate successful learning and academic performance (Nesbit and Adesope 2006; Siew 2020). Previous cross-sectional research has found that older students have different knowledge structures compared to



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rather than the *infinite array of values that the output of this function could take*. We might have contributed to this misunderstanding when claiming that a field is 'a quantity that has a magnitude for each point in space and time'. We should have clarified that the magnitude of a PPS measure can be seen as a specific sample from a field in the here and now rather than as a database containing all possible field values.

There is one further clarification we would like to make. Although all PPS measures reflect action value (at least under the perspective we propose), not all action values are reflected in PPS measures. The opinion of Noel and Serino about this issue is unclear because their title states that 'high action values occur near the body', implying that, for any type of action, action values *can only* be high when an object is near the body. However, they later specifically refer to contact creation/avoidance actions, implying that their title holds true only for this type of action. To be explicitly clear: our claim was that PPS measures reflect the value of only those actions which create or avoid contact with the body, and therefore are *in part* dependent on proximity to the body. There certainly are, however, action values which do not depend on body proximity. After all, it is undeniable that non-contact actions can be valuable, and that their value does not necessarily have anything to do with proximity: merely imagine tracking a distant cloud with your head to gather information about future storms.

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References

1. Noel, J.-P. and Serino, A. (2019) High action values occur near our body. *Trends Cogn. Sci.* 23, 269–270
2. Bufacchi, R.J. and Iannetti, G.D. (2018) An action field theory of peripersonal space. *Trends Cogn. Sci.* 22, 1076–1090
3. Cisek, P. and Kalaska, J.F. (2010) Neural mechanisms for interacting with a world full of action choices. *Annu. Rev. Neurosci.* 33, 269–298

Forum

A Semantic Network Cartography of the Creative Mind

Yoed N. Kenett[1,*] and Miriam Faust[2,3]

The role of semantic memory in creativity is theoretically assumed, but far from understood. In recent years, computational network science tools have been applied to investigate this role. These studies shed unique quantitative insights on the role of semantic memory structure in creativity, via measures of connectivity, distance, and structure.

What do we need to know to have creative ideas? Embedded in theories on creativity is the notion that knowledge plays a role in one's ability to generate creative ideas. The main theory relating creative thinking to semantic memory – the memory system that stores concepts and facts – is the associative theory of creativity [1]. According to this theory, creativity involves the connection of weakly related, remote concepts into novel and applicable concepts. The farther apart the concepts are, the more creative the new combination will be. For this new combination to be applicable – to make sense – a broad enough body of knowledge is required. Thus, the structure of semantic memory plays an important role in the creative process. Furthermore, this theory argues that low and high creative individuals differ in their structure of semantic memory, with high creative individuals having a structure that facilitates such a process [1]. However, this theory has been challenging to investigate due to the complexity of modeling and representing semantic memory, which would allow examination of this theory. Recently, computational methods to study knowledge and memory structure in creativity are paving the way to uniquely examine their role in the creative process [2–4] and examine the associative theory of creativity [1]. Here, we outline one such approach, based on the application of network science methodologies [5].

Network science is based on mathematical graph theory, providing quantitative methods to investigate complex systems as networks [5,6]. A network is comprised of nodes that represent the basic units of a system (semantic memory) and edges that signify the relations between them (semantic similarity). While the application of network science methodologies has become a popular approach to study brain structure and function [7], it has been used to study cognitive phenomena to a lesser extent. This is despite classic cognitive theory in language and memory being highly related to a network perspective [5,6,8]. By structuring memory as a network [5], network science can directly and quantitatively examine classic cognitive theory and the operations of cognitive processes such as those taking place during memory retrieval and associative thought [8]. Such an approach provides powerful quantitative methods to examine the structure and dynamics of

Kenett & Faust (2019)

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The Role of Knowledge in Creative Thinking

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ABSTRACT

In this invited paper, I briefly review my past, current, and future lines of research. The associative theory of creativity argues that higher creative individuals have a richer semantic memory structure that facilitates broader associative search processes, that leads to the combination of remote concepts into novel and appropriate ideas. Based on this theory, in my research I investigate the role of knowledge – or semantic memory – in high-level cognition, focusing on creativity, associative thinking, and memory search, in typical and clinical populations. To do so, I apply computational tools from network science, natural language processing, and machine learning, coupled with empirical cognitive and neural research. Such computational tools are enabling the representation and operationalization of the structure of semantic memory and the processes that operate over it. This is critical as it allows us to start quantifying issues that for a very long time were studied very subjectively in creativity research – remoteness of ideas, associative thinking, flexible/richer semantic memory structure, etc. Such work is offering unique, quantitative, ways to directly study classic theories of creativity, propelling forward our understanding of its complexity.

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Introduction

The human mind can be extremely flexible as we solve problems and create new ideas, in an increasingly complex world. How can we possibly study the complex multiple cognitive capacities that support such flexibility? More generally, how can we study the complex cognitive and neural processes and dynamics that give rise to higher-level cognition?

Creativity, as an example, involves multiple cognitive processes interacting together in complex dynamics—e.g., cognitive control, fluid intelligence, imagination, and memory (Benedek, Jauk, Sommer, Arendasy, & Neubauer, 2014) – but is far from understood. Creative ideation refers to the cognitive process of generating novel and effective ideas (Green, Beaty, Kenett, & Kaufman, 2023; Runco & Jaeger, 2012). Creative ideation is typically examined with divergent thinking (DT) tasks such as the alternative uses task (AUT) that pose open-ended problems and requires participants to come up with several creative solutions (Acar & Runco, 2019; Runco & Acar, 2012). Creative ideation – as measured with DT tasks – is the most thoroughly studied aspect of creativity, broadly viewed a critical component of creativity (Runco & Acar, 2012; Said-Metwaly, Taylor, Camarda, & Barbot, 2022).

My research centers around the role of knowledge – or, semantic memory – in high-level cognition, such as creativity (largely, creative ideation). Specifically, the role of semantic memory (memory of knowledge and facts) in creativity is theoretically acknowledged but traditionally only indirectly investigated (Abraham & Bubic, 2015). One reason for this omission is the challenge of representing the organization of semantic memory; a challenge that is compounded when modeling the cognitive processes that operate on semantic memory, such as learning or memory search processes (Hills & Kenett, 2022; Kumar, 2021).

The role of semantic memory structure in creativity has been most prominently highlighted by the associative theory of creativity (Mednick, 1962). According to this theory, individual differences in semantic memory structure influence creative thought. It proposed that higher creative individuals (scoring higher on creativity tests, such as the AUT) are characterized by "flat" associative hierarchies (numerous and weakly related associations to a given concept) rather than "steep" associative hierarchies (few and strong associations to a given concept) characterized in lower creative individuals (scoring lower on creativity tests, such as the AUT) in semantic memory (However, see Benedek & Neubauer, 2013). Creativity, the theory argues, is realized by the ability to associatively spread more broadly through such a semantic memory structure, connecting

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Kenett (2024)

Assessment

Recognizing creativity

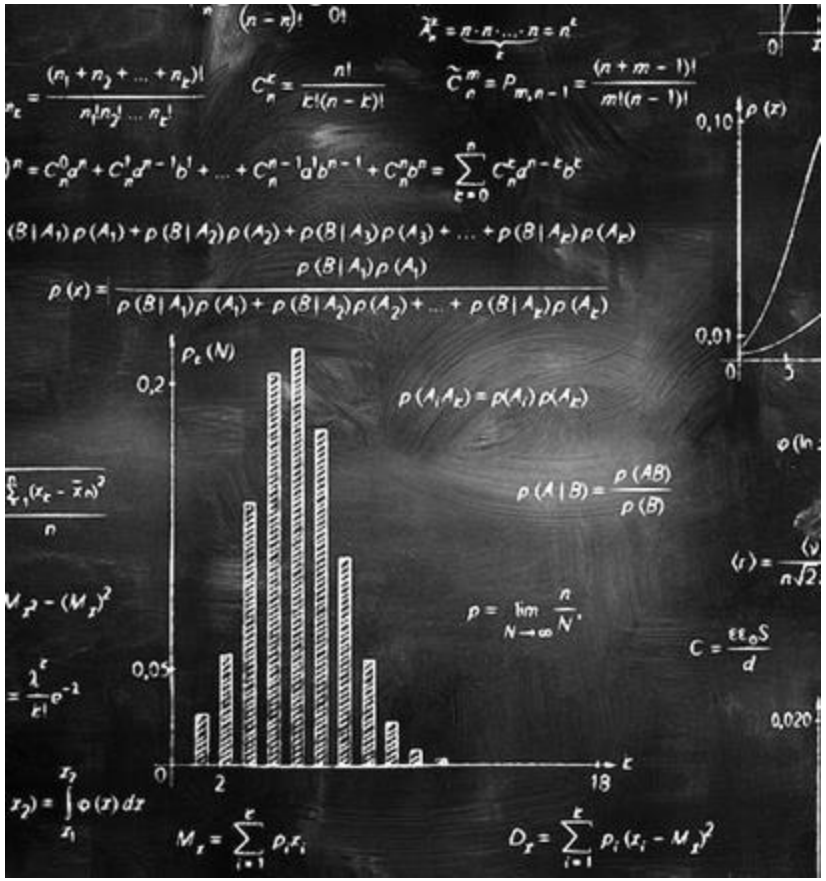
- **Memory** is more straightforward to test than creativity (agreement)
- Creativity is *unknown*, can't be **recognized**
- Easier to distinguish with **little-c** (e.g., my new poem is more original)
- Harder at higher-levels **Big-C**, requires domain expertise

Recognizing creativity: Consensus

- Creativity is a **social judgment**
- Producers → audience **interaction**
- **Consensus:** Art (hard) vs. science (easier?)

Recognizing creativity: It's not easy

- Studying creativity is **challenging**
- Movement, language, **consciousness** face similar challenges
- Consensus in the field on **product** (novel, appropriateness)



Subjective ratings by judges

- **Judges** are widely used to assess **performance** in other domains, such as sports

- Judges' assessments are often ***subjective***, but informed by their **expertise**

- **Usually,** judges' ratings are **reliable and valid**

Creative product: Consentual Assessment Technique

- **Experts** deem what is creative (aka "appropriate observers")
- **Pro:** very **flexible**; adopted to stories, poems, music compositions, math, etc.
- **Con:** exceedingly **subjective**; depends on expertise, agreement

Consensual Assessment Technique (CAT)

- Developed by **Teresa Amabile** in 1982
- Provides a **subjective** means to assess creativity
- According to Amabile, "a product is creative to the extent that expert raters **independently agree** upon this judgement"

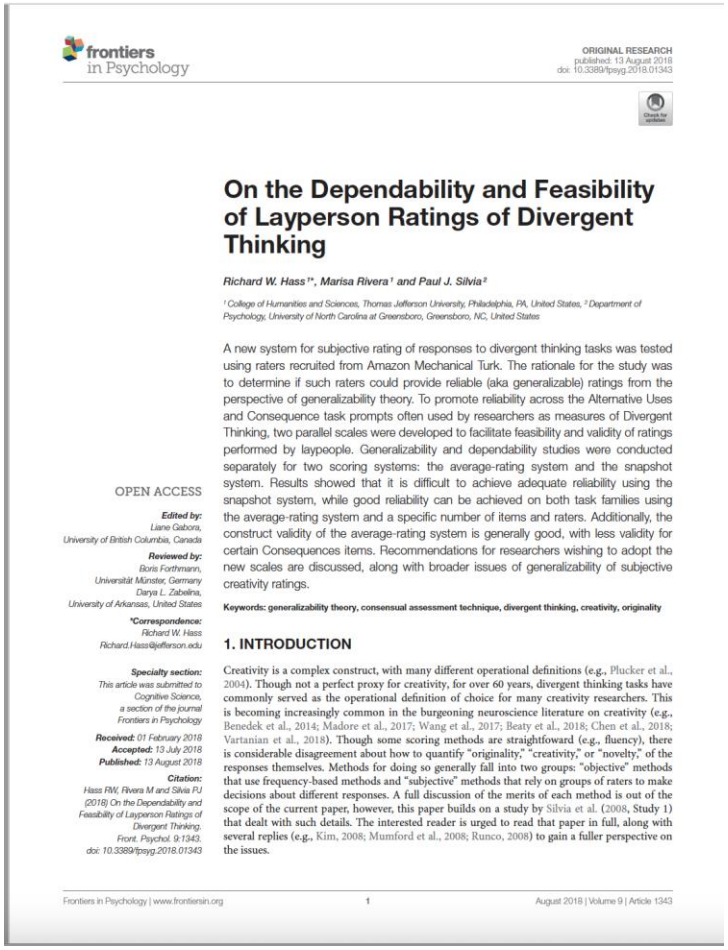
CAT procedure

- Raters/judges are **domain experts,** usually currently engaged in the relevant field
- Generally, the **more** raters the **better,** but at least 3 is recommended
- Raters can assess **products** from many **different fields**
  - Engineering (phone, computer)
  - Arts (painting, stories)

Experts vs. novice raters: Poetry

- Experts are **hard to recruit** for psychology experiments - can **novices** do just as well?
- Kaufman et al. (2008) asked 10 expert **poets** and 102 non-expert college students to **judge** 204 poems by other students (1-6 creativity scale)
- **Experts** were more **consistent** than novices

Can anyone do it?



frontiers in Psychology

ORIGINAL RESEARCH
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On the Dependability and Feasibility of Layperson Ratings of Divergent Thinking

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A new system for subjective rating of responses to divergent thinking tasks was tested using raters recruited from Amazon Mechanical Turk. The rationale for the study was to determine if such raters could provide reliable (aka generalizable) ratings from the perspective of generalizability theory. To promote reliability across the Alternative Uses and Consequence task prompts often used by researchers as measures of Divergent Thinking, two parallel scales were developed to facilitate feasibility and validity of ratings performed by laypeople. Generalizability and dependability studies were conducted separately for two scoring systems: the average-rating system and the snapshot system. Results showed that it is difficult to achieve adequate reliability using the snapshot system, while good reliability can be achieved on both task families using the average-rating system and a specific number of items and raters. Additionally, the construct validity of the average-rating system is generally good, with less validity for certain Consequences items. Recommendations for researchers wishing to adopt the new scales are discussed, along with broader issues of generalizability of subjective creativity ratings.

Keywords: generalizability theory, consensual assessment technique, divergent thinking, creativity, originality

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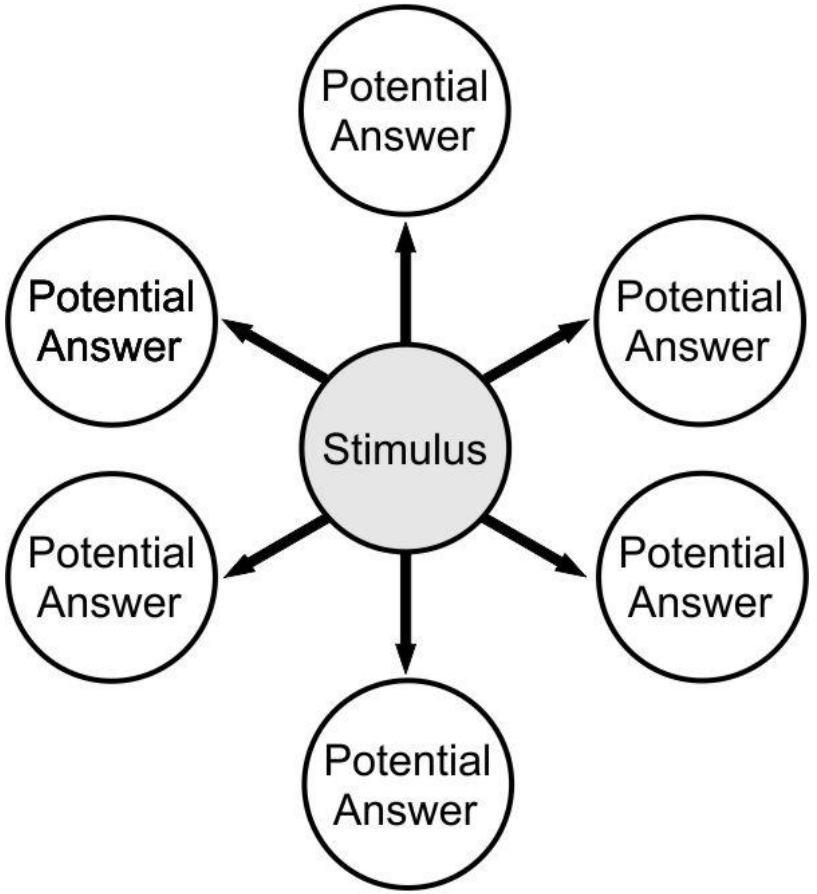
1. INTRODUCTION

Creativity is a complex construct, with many different operational definitions (e.g., Plucker et al., 2004). Though not a perfect proxy for creativity, for over 60 years, divergent thinking tasks have commonly served as the operational definition of choice for many creativity researchers. This is becoming increasingly common in the burgeoning neuroscience literature on creativity (e.g., Benedek et al., 2014; Madore et al., 2017; Wang et al., 2017; Beaty et al., 2018; Chen et al., 2018; Vartanian et al., 2018). Though some scoring methods are straightforward (e.g., fluency), there is considerable disagreement about how to quantify "originality," "creativity," or "novelty," of the responses themselves. Methods for doing so generally fall into two groups: "objective" methods that use frequency-based methods and "subjective" methods that rely on groups of raters to make decisions about different responses. A full discussion of the merits of each method is out of the scope of the current paper, however, this paper builds on a study by Silvia et al. (2008, Study 1) that dealt with such details. The interested reader is urged to read that paper in full, along with several replies (e.g., Kim, 2008; Mumford et al., 2008; Runco, 2008) to gain a fuller perspective on the issues.

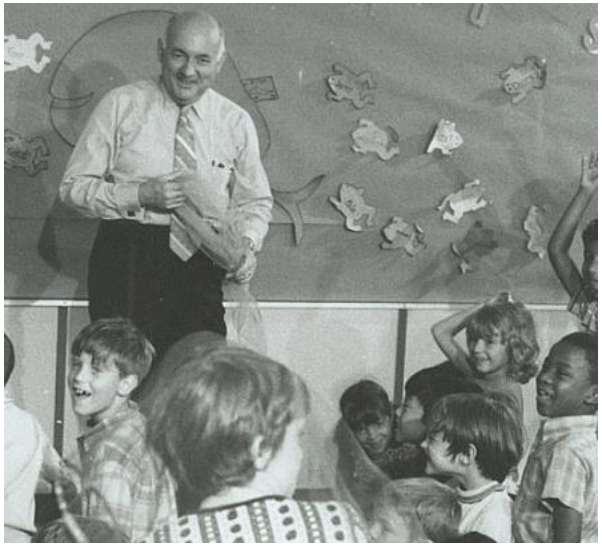
Divergent thinking

- Generate ideas that ***diverge*** from a concept
- **Verbal** and **figural** tasks assess divergent thinking
- Responses scored for **fluency, flexibility, originality, and elaboration**



Torrance Test of creative thinking (TTCT)

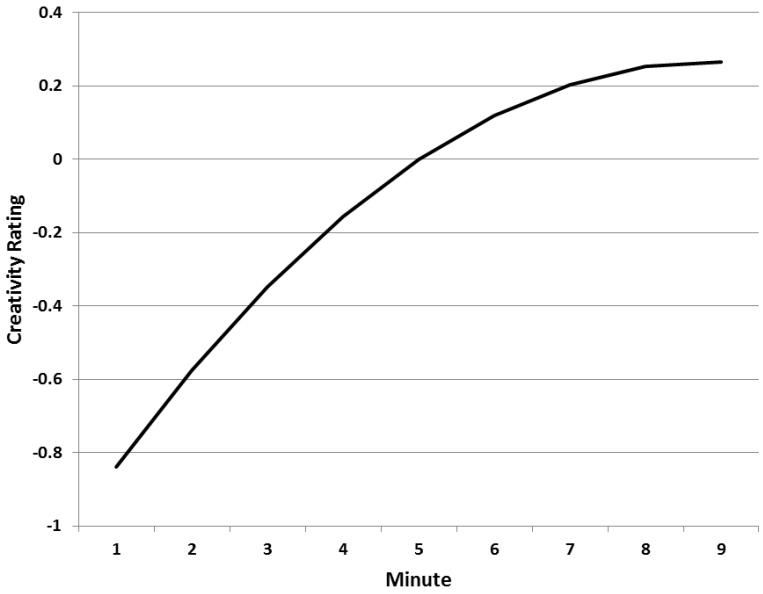
- Developed by E. Paul Torrence in the 1960s
- Built on the work of J.P. Guilford, who focused on **intelligence** and defining **cognitive aspects** of creative thinking
- TTCT measures **verbal** and **figural** creativity



Divergent thinking

The serial order effect

- **Obvious** ideas/uses typically come to mind **first** (high fluency)
- It **takes time** to move beyond obvious ideas
- People can get **"stuck"** on physical characteristics of object
  - E.g., brick
  - Red, rectangle, rough texture, heavy, etc. f



Strategies in generating uses?

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Divergent thinking: Strategies and executive involvement in generating novel uses for familiar objects

K. J. Gilhooly[1]*, E. Fioratou[1], S. H. Anthony[1] and V. Wynn[2]
[1]University of Hertfordshire, UK
[2]Oxford Brookes University, UK

Although the Alternative Uses divergent thinking task has been widely used in psychometric and experimental studies of creativity, the cognitive processes underlying this task have not been examined in detail before the two studies are reported here. In Experiment 1, a verbal protocol analysis study of the Alternative Uses task was carried out with a Think aloud group ($N = 40$) and a Silent control group ($N = 64$). The groups did not differ in fluency or novelty of idea production indicating no verbal overshadowing. Analysis of protocols from the Think aloud group suggested that initial responses were based on a strategy of Retrieval from long-term memory of pre-known uses. Later responses tended to be based on a small number of other strategies: property-use generation, imagined Disassembly of the target object into components and scanning of Broad Use categories for possible uses of the target item. Novelty of uses was particularly associated with the Disassembly strategy. Experiment 2 ($N = 103$) addressed the role of executive processes in generating new and previously known uses by examining individual differences in category fluency, letter fluency and divergent task performance. After completing the task, participants were asked to indicate which of their responses were new for them. It was predicted and found in regression analyses that letter fluency (an executively loading task) was related to production of 'new' uses and category fluency was related to production of 'old' uses but not vice versa.

The ability to generate many different possible solutions to a problem is an important aspect of creative thinking and has been specifically addressed in the psychometric tradition by means of *divergent thinking* tests (Guilford, 1971; Guilford, Christensen, Merrifield, & Wilson, 1978) in which participants are asked to generate as many alternative solutions as they can (Plucker & Renzulli, 1999). These tests contrast with *convergent thinking* tests in which there is but a single solution, e.g. Raven's Matrices (1960) and other standard intelligence tests. The Alternative Uses task is a prototypical divergent task in which the goal is to generate many possible uses, different from the

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A Novel Coding Scheme for Assessing Responses in Divergent Thinking: An Embodied Approach

Heath E. Matheson and Yoed N. Kenett
University of Pennsylvania

In this study, we devised a novel coding scheme for responses generated in a divergent thinking (DT) task. Based on considerations from behavioral and neurocognitive research from an embodied perspective, our scheme aims to capture dimensions of simulations of action or the body. In an exploratory investigation, we applied our novel coding scheme to analyze responses from a previously published dataset of DT responses. We show that (a) these dimensions are reliably coded by naïve raters and that (b) individual differences in creativity influences the way in which different dimensions are used over time. Overall, our results provide new hypotheses about the generation of creative response in the DT task and should serve to characterize the cognitive strategies used in creative endeavors.

Keywords: embodied cognition, divergent thinking, creativity, cognitive strategies

Supplemental materials: http://dx.doi.org/10.1037/aca0000297.supp

Creative thinking is defined by the ability to generate novel and appropriate new ideas (Runco & Jaeger, 2012; Simonton, 2016; Sowden, Pringle, & Gabora, 2014). Commonly applied creativity tasks are divergent thinking (DT) tasks that require participants to generate responses to open-ended questions (Acar & Runco, 2019; Runco & Acar, 2012). For instance, in the alternative uses task, participants are required to generate alternative, novel, and creative uses to common objects (Torrance, 1966). When shown the image of a shoe, a participant in this task may suggest that the sole of the shoe could be used to hammer a nail into the wall. Typically, these responses are then measured on various dimensions such as novelty, uniqueness, or appropriateness (see Vartanian et al., 2019 for a review). While DT tasks have been applied in creativity research for decades, research has solely focused on the outputs in this task and very little is known about the cognitive strategies that people use when required to generate such creative, alternative uses (Hennessey & Amabile, 2010; Runco & Acar, 2012). The limited research examining potential strategies suggests that individuals examine potential action related uses when generating responses (Gilhooly, Fioratou, Anthony, & Wynn, 2007). The aim of the current study is to expand the extant research on potential cognitive strategies using an embodied cognition framework.

Currently, to the best of our knowledge, only a small number of attempts have been made to characterize the types of strategies participants use by analyzing the content of verbal responses in DT. First, Gilhooly et al. (2007) found that participants tend to focus on the properties of objects, imagine disassembling them, and produce broad uses that may serve a creative purpose (e.g., a shoe as art).This finding is supported by research that has explicitly instructed participants to disassemble the objects. For instance, studies have shown that instructions to use the disassembly strategy do indeed increase the creativity of people's DT responses (Nusbaum & Silvia, 2011; Wilken, Forthmann, & Holling, 2019). This also occurs for other tasks, including figural DT (Forthmann et al., 2016). Similarly, an early exploratory study used a think-aloud protocol during a DT and showed that responses could be reliably sorted into categories related to structuring the problem, performing a memory search, and evaluating the outcome (Khandwalla, 1993). Importantly, this study suggested that one of the most effective strategies was "probing" or "elaborating" on possible solutions, and from their examples given, this appeared often to involve the disassembly strategy. These findings support the idea that the disassembly cognitive strategy successfully contributes to creative performance.

Taking a different approach, Chrysikou, Motyka, Nigro, Yang, and Thompson-Schill (2016) developed a coding scheme that assessed whether participants relied on the concrete perceptual attributes of objects in producing their DT responses. The authors found that participants showed that participants were more likely to rely on concrete properties when generating responses to words versus pictures. More current research has focused on whether

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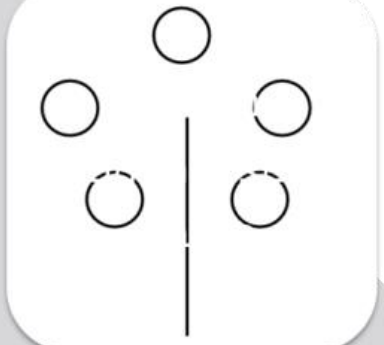
Tel-Aviv Creativity Test

What are all the things you can do with a newspaper?



In what way are carrot and potato similar?

Convergent thinking

אין להפוך דף זה עד שתתקבל הוראה מפורשת!

הנחיות:

מעברו השני של עמוד זה, מופיעות 25 חידות. כל חידה מורכבת משלוש מילים נפרדות. אתם מתבקשים למצוא את המילה היוצרת צירוף בעל משמעות עם כל אחת ממילות החידה בנפרד.

לדוגמה:

רגל יד עור _____

התשובה לחידה זו היא המילה "פשיטה", היוצרת צירוף חדש עם כל אחת מהמילים: פשיטת רגל, פשיטת יד, פשיטת עור.

חרום לפי טובה _____

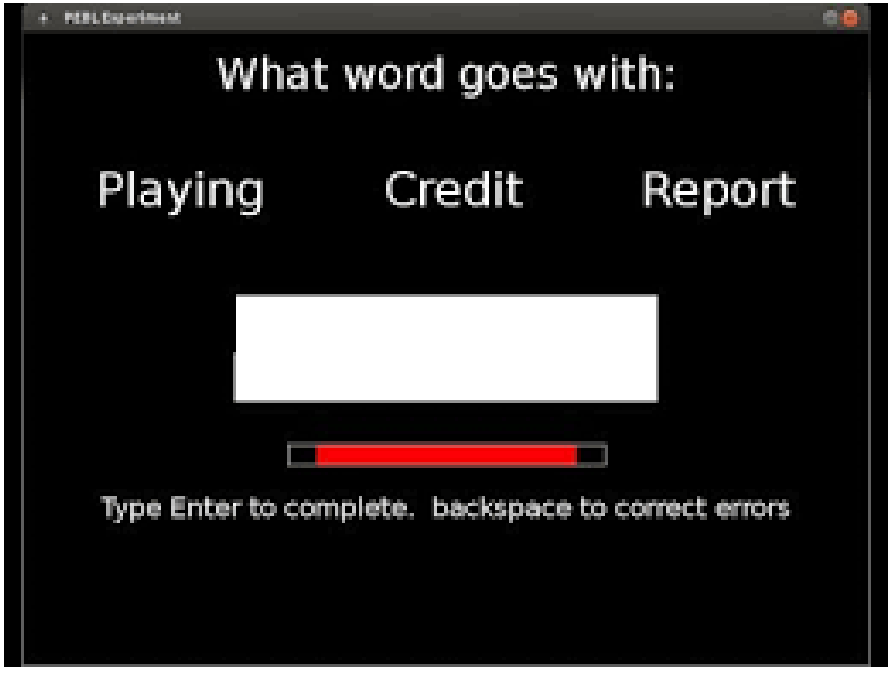
התשובה לחידה זו היא המילה "שעה", היוצרת צירוף חדש עם כל אחת מהמילים: שעת חרום, לפי שעה, בשעה טובה.

ליצירת הצירוף, ניתן להוסיף למילה מיליות יחס (לדוגמה- **ב**שעה, **ל**שעה, **כ**שעה) ולהפוך את מילות החידה או התשובה מיחיד לרבים וההיפך.

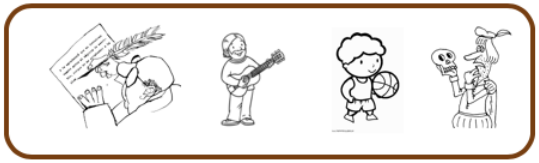
לכל חידה תשובה אחת בלבד.

משך הזמן המוקצב לפתרון החידות: 15 דקות. עליכם לפתור כמה שיותר חידות בזמן המוקצב, כאשר מותר לדלג על חידה קשה ולחזור אליה לאחר מכן.

אין להפוך דף זה עד שתתקבל הוראה מפורשת!



Self reports



ICAA: Inventory of creative activities and achievements

	Music	Cooking	Visual arts	Science and engineering
Literature		Art and crafts	Sport	Performing arts

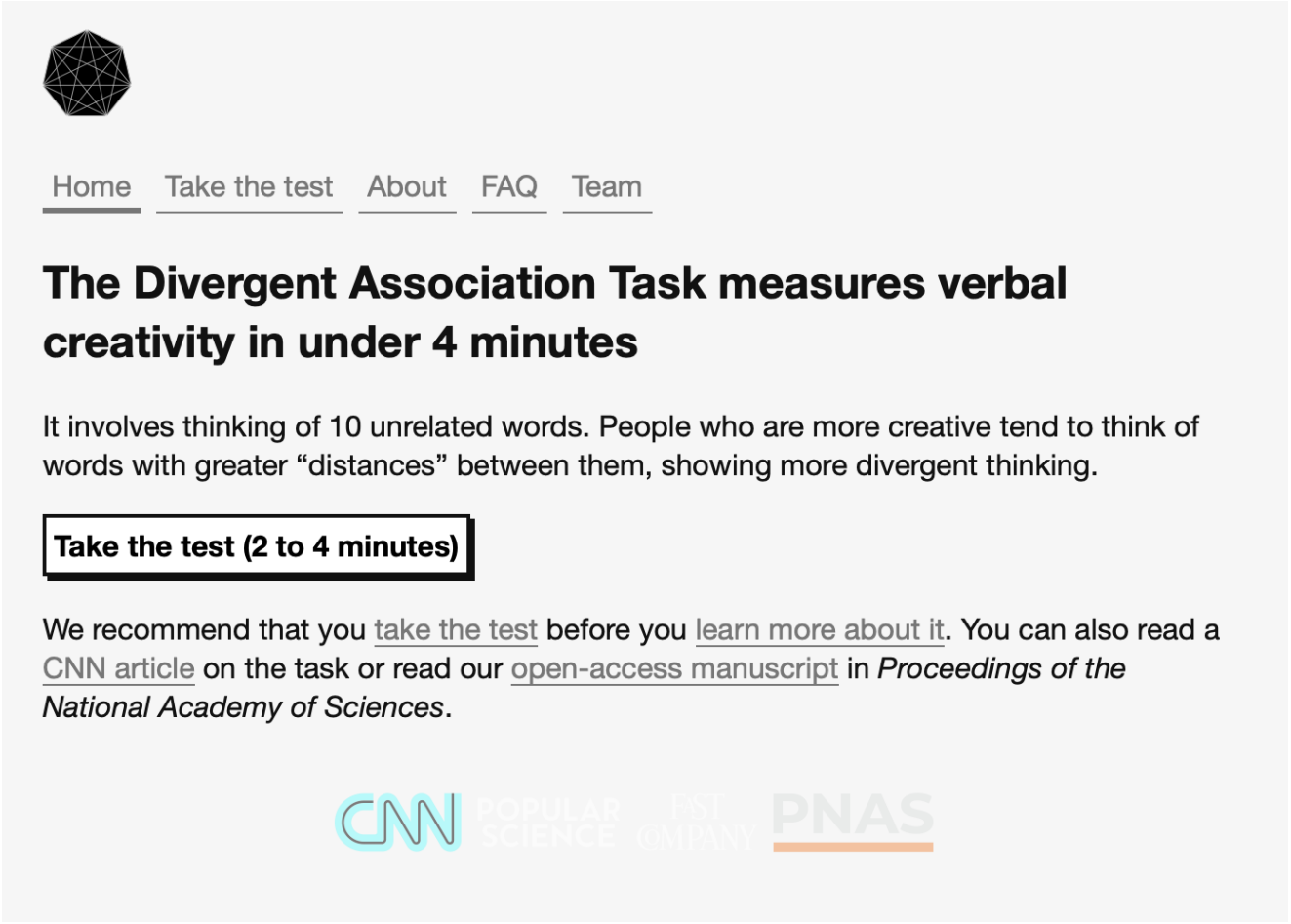
Creative activities

frequency in which participants engaged in various creative activities

Creative achievements

level of achievement acquired in a creative domain

Divergence associates task



https://www.datcreativity.com

Closed- and open-ended problem-solving

Closed

"When Josh leaves the factory where he works, all he has ever taken with him is a toolbox containing only his very own tools. No lunch box, no backpack, no bags, nothing in his pockets, etc. Yet, after a month he is arrested for grand theft from the site. Explain briefly what Josh was stealing.

Open




Scientific creativity thinking test

THE SCIENTIFIC CREATIVE THINKING TEST (SCTT)

The Scientific Creative Thinking Test (SCTT): Reliability, Validity, and Automated Scoring

Roger E. Beaty[1], Robert A. Cortes[2], Simone Luchini[3], John D. Patterson[1], Boris Forthmann[3], Brendan S. Baker[1], Baptiste Barbot[4,5], Mariale Hardiman[6], & Adam E. Green[2]

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[2] Department of Psychology, Georgetown University, United States

[3] Institute of Psychology, University of Münster, Germany

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Author Note

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Also

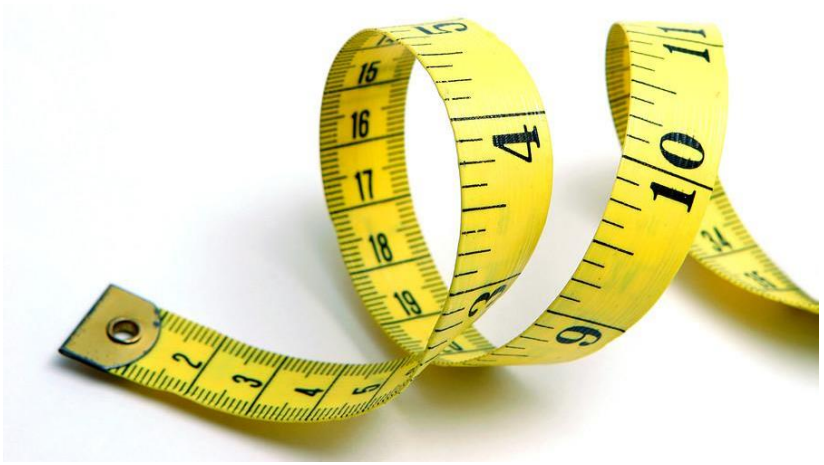
- Insight problems
- Analogies, metaphors, jokes
- Domain specific creative tasks
- …

Automating creativity assessment

- Current creativity assessment has **several limitations**
- **Time-consuming:** often rating thousands of responses
- **Subjective:** raters vary on what they find creativity
- Limits for **education**: teachers already overworked

Do creativity tasks measure anything?

- Validity: does a test measure what you think it measures?
- Do divergent thinking tasks have any validity?



Questions

Riddle me this

- What are questions?
- What are good questions?
- Why ask questions?

Shoutout

DIVISION 10 Psychology of Aesthetics, Creativity, and the Arts

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The Role of Asking More Complex Questions in Creative Thinking

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Question asking has been a critical tool for teaching and learning since the time of Socrates and is important in the creative problem-solving process. Yet, its role in creativity has insofar not been thoroughly explored. The current study assessed the role of question asking in the creative process. A correlational preregistered design was used to administer the alternative questions task (AQT) to explore its relation to cognitive and creative divergent thinking tasks. In the AQT—which is based on Torrance's unusual questions task—participants are asked to generate creative and unusual questions for common objects. Responses are rated for their question level using the Bloom's taxonomy, a widely accepted guideline in designing examination questions of differing levels of complexity, as well as their subjective and objective creativity. A significant positive relation between AQT question level and objective and subjective creativity scores was found: Higher, more complex questions were more creative, with the inverse effect for lower-level questions. We interpret these findings as supporting the hypothesis that higher question complexity is related and predictive of creative ability. A second study replicated and generalized our findings. Thus, our findings uniquely highlight the role of question asking, and especially question complexity, in creativity.

Keywords: creativity, question asking, Bloom taxonomy, divergent thinking

Creativity entails both idea originality and appropriateness (Runco & Jaeger, 2012). Thus, creative ideas or solutions require skilled problem solvers to search their memory and "move away" from common ideas toward ideas that are more novel or conceptually distant (Abraham & Bubic, 2015; Beaty & Kenett, 2023; Benedek et al., 2023; Kenett, 2018; Kenett & Faust, 2019; Volle, 2018). However, creative thinking is also critically motivated by information-seeking behaviors that are driven by curiosity and the personality trait openness to experience (Kenett et al., 2023). Such information-seeking tendencies likely promote problem finding, the first stage in the creative problem-solving process (Reiter-Palmon & Robinson, 2009).

Problem finding is considered the first stage of the creative problem-solving process but is still far from being understood (Okuda et al., 1991). It can be defined in general terms as the process or processes that precede problem solving (i.e., occurring before a problem can be solved). Operationally, it may involve the identification of a problem or the definition of an ambiguous situation into a workable problem or the raising of questions from ill-defined problem situations (Getzels, 1979; Runco & Nemiro, 1994).

Ill-defined problems often entail multiple, even sometimes conflicting, goals (Getzels, 1979; Schraw et al., 1995). There are multiple possible approaches to solve ill-defined problems. Before ideas can be generated, then evaluated, and selected for implementation, a process is needed to conceptualize and structure the ill-defined problem. During the problem finding process, an individual identifies, assesses, and structures a problem (Reiter-Palmon & Robinson, 2009). Constructing a new or unique approach to solving a problem makes the generation of creative ideas for solving the problem possible (Yang et al., 2022).

Past research indicates that problem finding and construction are positively related to creative problem solving (Mumford et al., 1991, 1994; Reiter-Palmon et al., 1997, 1998) and to divergent thinking measures of creativity (Abdulla et al., 2020; Alabbasi et al., 2023; Arreola & Reiter-Palmon, 2016). Reiter-Palmon et al. (1997, 1998) have found that people who excel at problem-finding tend to restate problems as questions, resulting in ambiguous or ill-defined problems. The researchers measured problem-finding ability based on the quality and originality of these restatements. However, much is still unknown about the specific types of these questions asked and their relationship to creative thinking.

The aim of the current study was to reintroduce the assessment of question asking in creativity research by using a creative questions task, and by utilizing current computational semantic distance methods to quantitatively assess participants' questions and their creativity. Critically, we focus on the role of question complexity in creativity, via an established taxonomy of learning objectives (the Bloom taxonomy).

Question Asking

An important but understudied part of creativity that likely facilitates information seeking behavior is question asking ability. In fact, question asking has been shown in the past to be part of the creative

Editor's Note. Roni Reiter-Palmon is the book editor for the journal.

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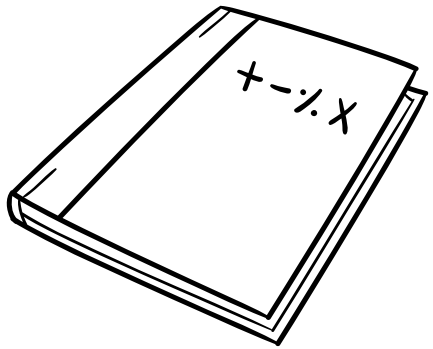
Tuval Raz

Prof. Roni Reiter-Palmon

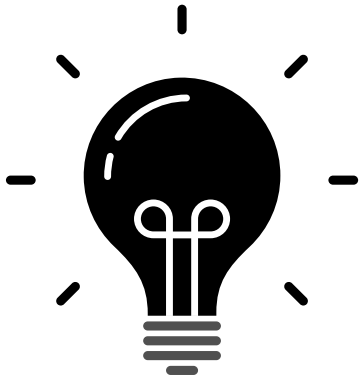
Problem Finding

- The first stage of the creative problem-solving process
- Problem restatements
- However, much is still unknown



Question asking

- An important but understudied part of creativity
- Torrance Test of Creative Thinking
- Higher-level, or complex, questions are considered critical in creativity
- But how to study?

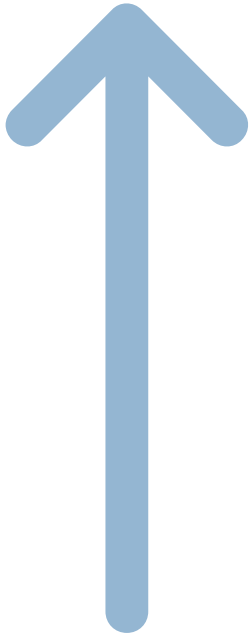


The alternative questions task

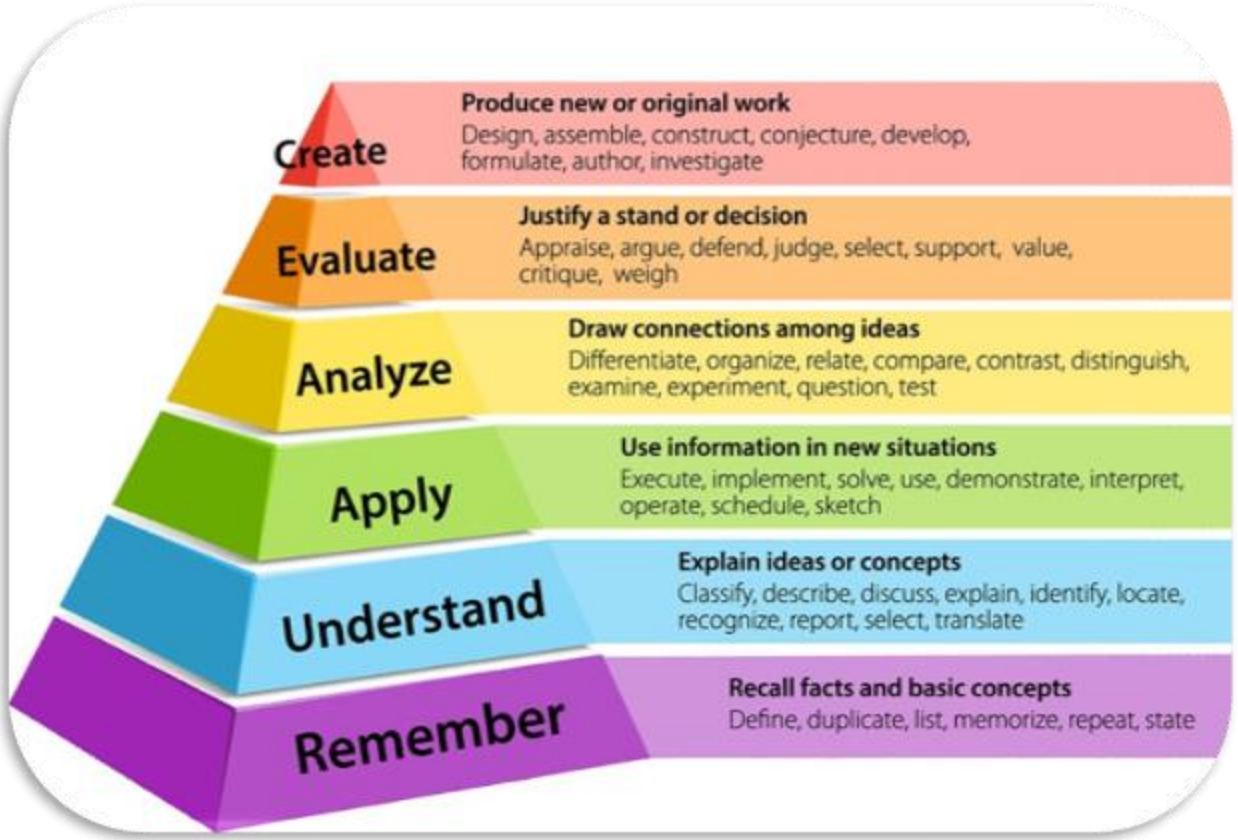
What are all the creative questions you can ask about these objects?

Bloom's Taxonomy (Bloom et al., 1956)

More Complex



Less Complex



Research

- **Participants:**
  - Study 1: N = 109 (50.4% female, mean age = 26.1 years, SD = 6.4; mean education = 13.5 years, SD = 5)
  - Study 2: N = 114 (47.5% female, mean age = 25.5 years, SD = 7.24; mean education = 14.4 years, SD = 4.4)

- **Tasks:** The Alternative questions task, AUT, personality, intelligence, curiosity

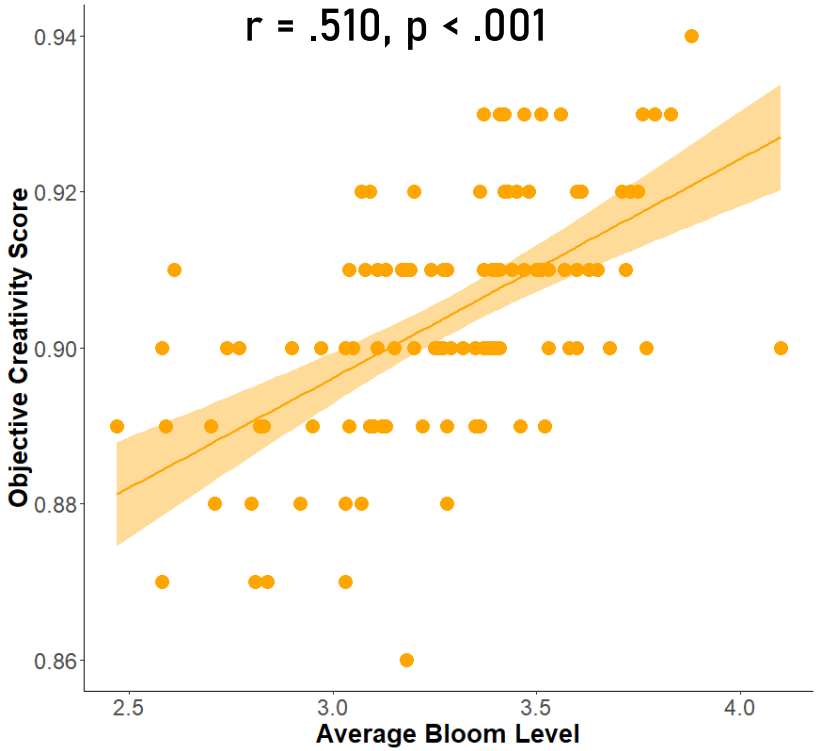
AUT and AQT assessment

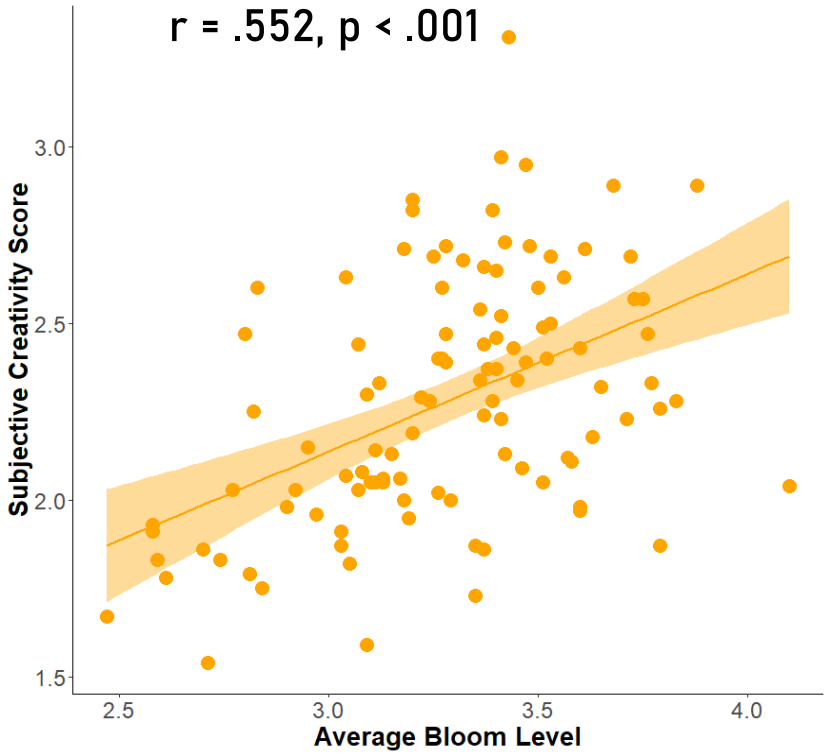
- **Fluency:** Number of responses
- **Subjective Creativity:** Scored using five online raters from Prolific
- **Objective Creativity:** Maximum Associative Distance Scores
- **Bloom Taxonomy level:** Scored for respective Bloom level

Examples

Bloom Level	Example
Remembering	Why isn’t it hard?
Understanding	What is it for?
Applying	What's the most convenient pillow?
Analyzing	Do you like to put your hand inside the pillowcase while sleeping?
Evaluating	Do you prefer to have the buttons of the pillowcase to be on the left or right?
Creating	Would it be possible to create biodegradable pillows, since after years of use, they're gross and unrecyclable?

Results: Bloom level & creativity





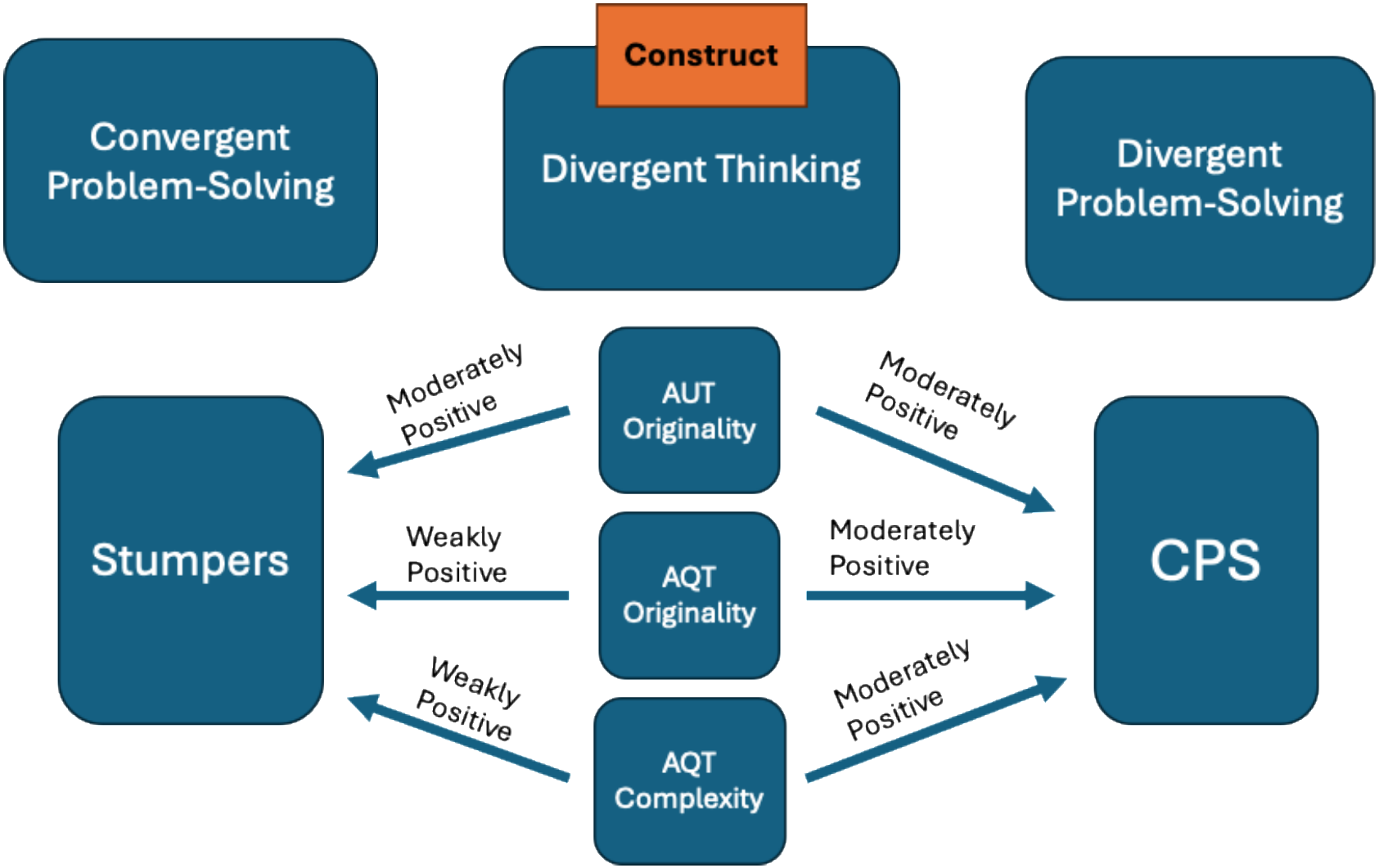
Results: Individual Bloom Level

Bloom Level	AQT Objective (Fluency Controlled)	AQT Subjective (Fluency Controlled)
Level 1	-.339 ***	-. 363 ***
Level 2	-. 328 ***	-. 295 ***
Level 3	-.206 *	n.s
Level 4	.355***	.315 ***
Level 5	.404 ***	.271 **

Follow-up research

- Automatic scoring of question complexity
- The role of question asking in open- and closed-ended problems
- The neural correlates of question asking
- Question asking ad aging
- Question asking training
- Question asking and prompt engineering
- Social aspects of question asking
- Questions asked by journalists in interviews
- …

The role of question asking in open-ended and closed-ended problems



Question asking & prompt engineering

Skill	Application in Question-Asking	Application in Prompt-Engineering
Creativity	Crafting inquiries that provoke thought and encourage exploration.	Designing prompts that elicit desired and insightful responses from AI.
Clarity and Precision	Articulating thoughts and ideas clearly and concisely.	Conveying instructions precisely to minimize misunderstandings.
Adaptability	Adjusting inquiries based on the audience's knowledge level and interests.	Tailoring prompts to the task and language model capabilities.
Critical Thinking	Stimulating deeper analysis and reflection through strategic questioning.	Considering potential outcomes and responses for meaningful interactions.
Empathy	Formulating respectful, inclusive inquiries that encourage open communication.	Optimizing language model responses through empathetic consideration.
Cognitive Flexibility	Approaching problems from different angles and modifying questions based on the conversation.	Iterating with various prompts to optimize results.
Goal-Orientation	Aiming to obtain relevant information or insights for specific issues.	Eliciting specific responses that align with the intended purpose.

Bloom's Taxonomy Level	Description	Example Prompt
Remembering	Retrieving relevant knowledge.	"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.	"Explain the significance of the water cycle to Earth's climate system."
Applying	Carrying out or using a procedure in a given situation.	"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.	"Compare and contrast the economic impacts of renewable vs. non-renewable energy sources."
Evaluating	Making judgments based on criteria and standards.	"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.	"Design a sustainable city plan that incorporates green energy, efficient public transport, and supports local biodiversity."

The importance of asking complex questions

- Asking more complex questions facilitates problem finding that leads to creativity
- Question asking facilitates open-ended problem solving
- Question asking is critical in prompt engineering & human-AI interactions

Summary

- Knowledge
- Assessment
- Question asking