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FACULTY OF DATA
AND DECISION SCIENCES
MAKING SENSE OF IT

CREATIVE THINKING

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A little about myself

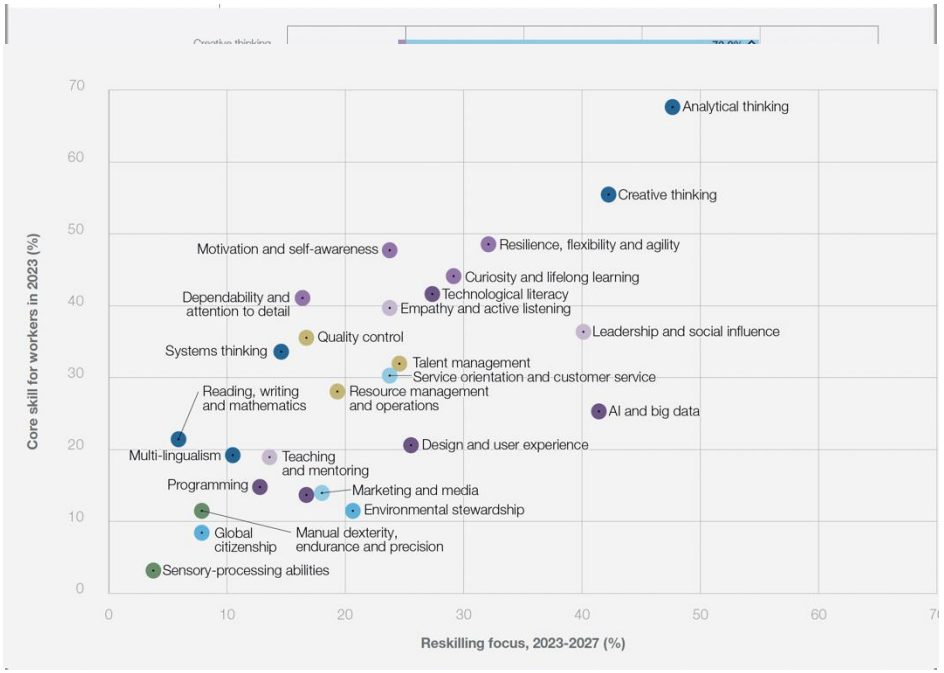
https://cognitive-complexity.net.technion.ac.il

Agenda

- Create a bridge between science and education related to creativity sciences

- Advocate for the significance of incorporaring creativity assessment and development in the classroom

Why does it matter?



Creativity: Myths & Facts

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Creativity myths: Prevalence and correlates of misconceptions on creativity

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ABSTRACT

Myths about creativity keep contributing to its mysterious aura despite our increasing scientific understanding of this complex phenomenon. This study examined the prevalence of known creativity myths across six countries from diverse cultural backgrounds and explored why some people believe in them more than others. Results revealed persistent, wide-spread biases in the public conception of creativity, such as attributing creative achievements to spontaneity and chance rather than persistence and expertise. Firmer belief in creativity myths was related to lower education, stronger reliance on undependable sources, and personality traits reflecting the willingness to accept questionable notions and to rely on opinions of others. The findings highlight the need for better communication of evidence-based knowledge to enable more effective support for creativity.

"For every complex problem there is an answer that is clear, simple and wrong".

(Henry L. Mencken)

1. Introduction

A common challenge to the effective realization of creativity is knowing too little about it, but it may be even worse when we assume to know but are wrong. Creativity myths—popular beliefs about creativity that are not supported by scientific evidence—keep contributing to the mystery associated with creativity. Over the last few decades, research has increasingly demystified this complex phenomenon, arriving at the conclusion that creativity can be understood as the "extraordinary result of ordinary processes" (Sternberg & Lubart, 1996, p. 681). Yet, misconceptions about creativity are still commonly encountered, suggesting that scientific findings have not sufficiently penetrated public perceptions, which may undermine attempts to foster creativity in education or at work (Baas et al., 2015; Boden, 2004). To better understand the extent of and reasons for beliefs in creativity myths, this study examined their current prevalence across a culturally diverse sample and explored predictors of why some people believe in them more than others.

Research has identified various myths and misconceptions commonly held by popular psychology (Furnham & Horne, 2021; Lilienfeld et al., 2010). Known misconceptions regarding creativity refer to all aspects of the construct including its definition, the creative process, characteristics of creative people, and how to foster creative performance (Cropley, 2016; Gilhooly, 1999; Kaufman, 2015; Kim, 2019). For example, creativity is sometimes seen as synonymous with arts, ignoring the fact that creativity can be expressed in virtually any domain, such as in science, social relationships, or even crime (Glăveanu, 2014). Regarding the creative process, creative thinking is commonly considered as uncontrollable and subject to spontaneous inspiration, whereas research increasingly highlights the strategic and controllable aspects of creative cognition (Benedek & Jauk, 2019; Silvia, 2018). There are mixed misconceptions regarding the characteristics of creative people.

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Myth or fact? 1/2

- Teachers appreciate the idea of creativity but not necessarily creative pupils
- Creative people are usually more intelligent
- A man's creativity increases his attractiveness to potential partners
- Getting rewarded for creative performance at work increases their productivity

Myth or fact? 1/2

- Tea ut not nece
- Cre
- A m s to pote
- Get at wor

Myth or fact? 2/2

- Creativity “sits” in the right hemisphere of the brain
- Creativity cannot be measured
- Children are more creative than adults
- Creative ideas are naturally a good thing
- Creative accomplishents are usually the result of a sudden inspiration

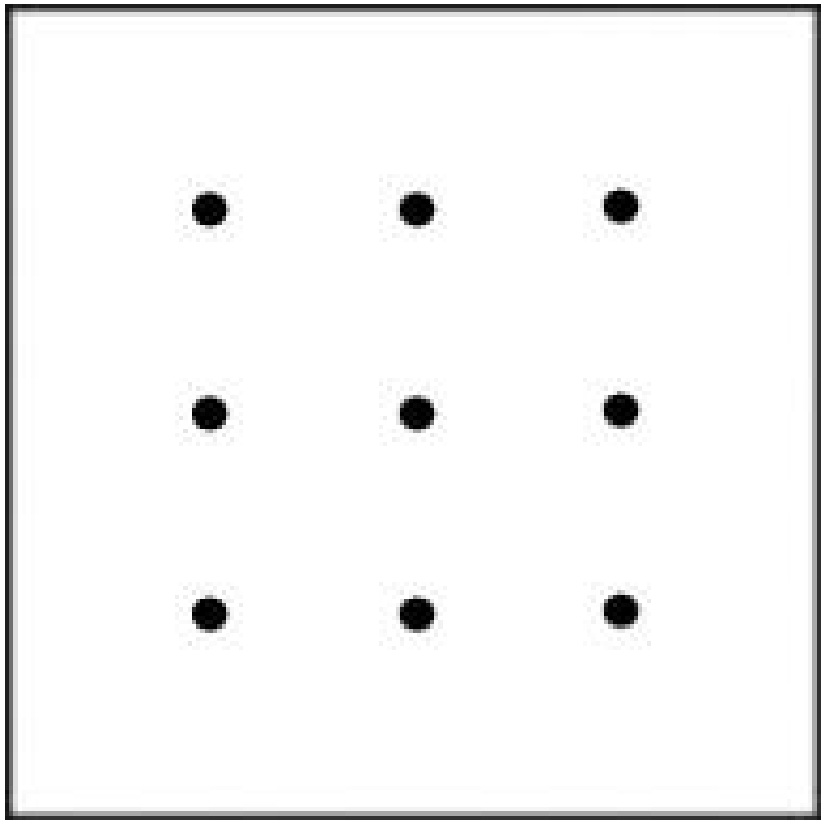
Myth or fact? 2/2

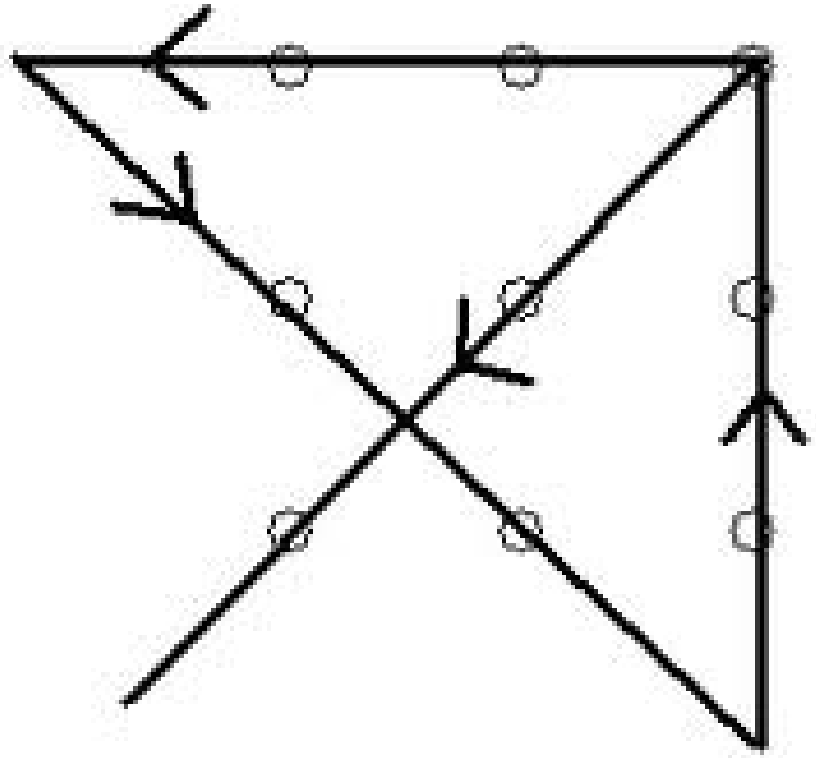
- Crec … e brain
- Crec …
- Chil…
- Crec …
- Crec … lt of a sudc …

Intro to creativity

A few examples

Challenge #1 – the nine dot problem





Challenge #2

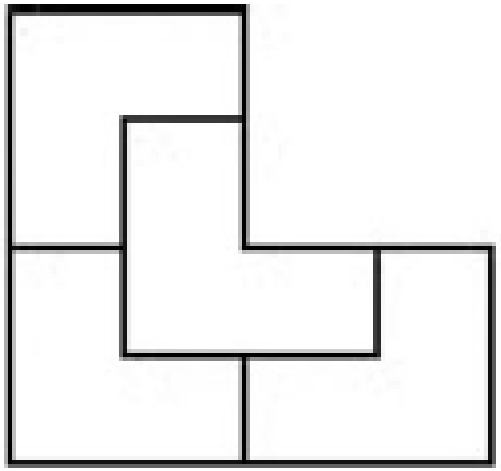
A father and his son took a road trip with a bunch of the son's friends. Unfortunately, they had a serious car accident. The father died immediately and the son was rushed to a nearby hospital

Luckily, the head of the surgery department – the toughest, most energetic, powerful and feared from physician – was in the hospital. After closely examining the patient, the head of the department said: "I can't do it, I can't operate on my son"

Challenge #3 – the farm problem

- Divide an L shaped farm into four parts that have the same size and shape

Solution:



Challenge #4 – radiation problem

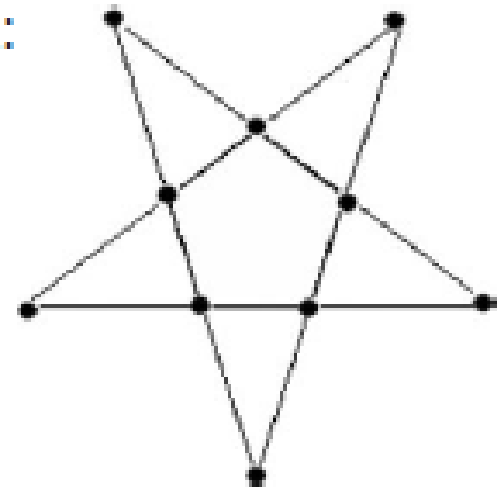
- A patient has an inoperable tumor in the middle of the body. There is a ray at a strong intensity that can destroy the tumor, but the ray also harms the healthy tissue that it travels through. At low intensities, the ray will spare the health tissue but will not destroy the tumor.

- Think out a way to use the ray to destroy the tumor without damaging healthy tissue.

Challenge #5 – tree problem

- Plant 10 trees in five rows with four trees in each row

Solution:



(The dots represent trees)

Challenge #6 – matchstick problems

General

So what is it??

creativity *noun*

Save Word

cre·a·tiv·i·ty | \ ˌkrē-(ˌ)ā-ˈti-və-tē, ˌkrē-ə- \

Definition of *creativity*

1 : the ability to create
// her artistic *creativity*

2 : the quality of being creative

The complexity of creative thinking

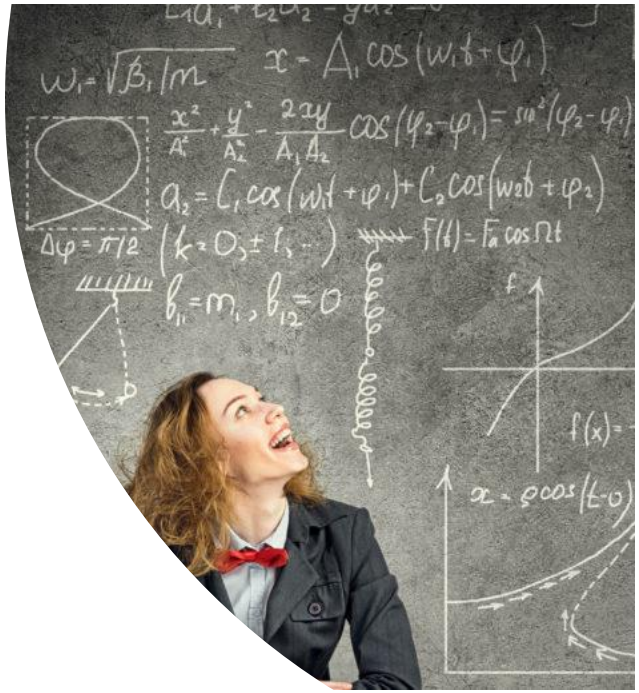
What is creativity?

- We really don't know
- Ill-defined concept (i.e. time, consciousness, ethics…)
- Is it –
  - Generation? Innovation? Originality? Uniqueness? Thinking outside the box?

- Artistic creativity versus scientific creativity vs. every-day creativity

Creativity as a science

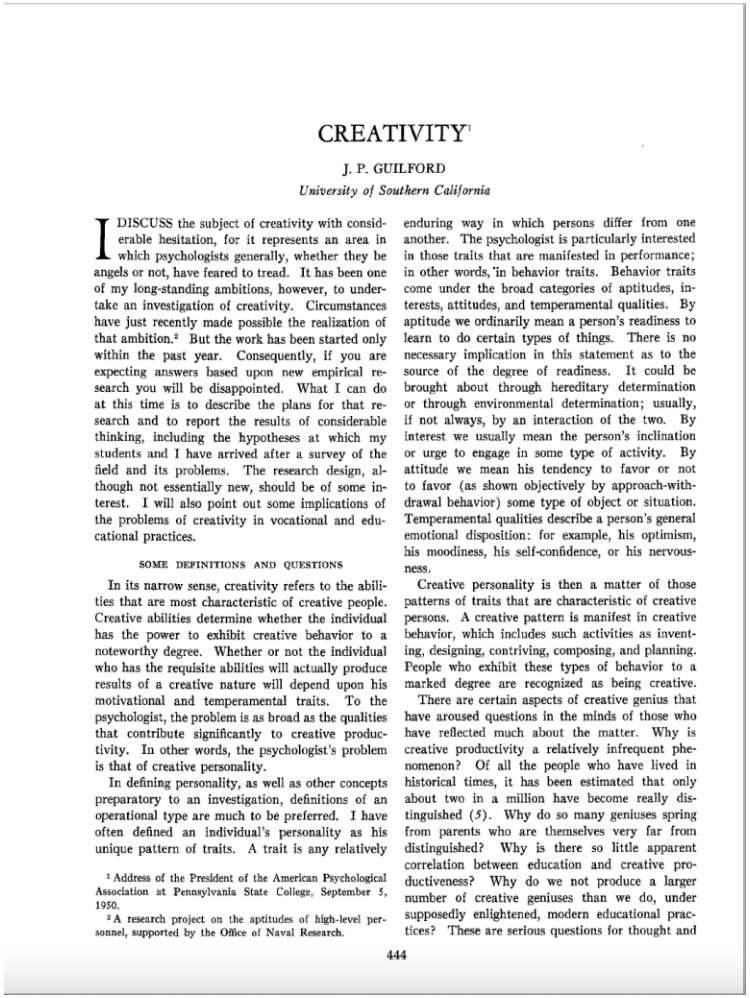
- Creativity has come a long way
- Once viewed as mysterious workings of the gods (some still do!)
- Modern science considers creativity to be result of measurable psychological processes



The scientific "revolutions" in creativity research

- The cognitive revolution of the early 1990's
  - Studying creativity within 'ordinary' cognitive capacities, such as language, memory, and attention
- The neuroscientific revolution of the early 2000's
  - Elucidate how the brain supports creative processes
- The computational revolution of the mid 2010's
  - Utilizing computational tools to quantitatively assess and predict creativity

J. P. Guilford's presidential address (1950)



CREATIVITY[1]

J. P. GUILFORD
University of Southern California

I DISCUSS the subject of creativity with considerable hesitation, for it represents an area in which psychologists generally, whether they be angels or not, have feared to tread. It has been one of my long-standing ambitions, however, to undertake an investigation of creativity. Circumstances have just recently made possible the realization of that ambition.[2] But the work has been started only within the past year. Consequently, if you are expecting answers based upon new empirical research you will be disappointed. What I can do at this time is to describe the plans for that research and to report the results of considerable thinking, including the hypotheses at which my students and I have arrived after a survey of the field and its problems. The research design, although not essentially new, should be of some interest. I will also point out some implications of the problems of creativity in vocational and educational practices.

SOME DEFINITIONS AND QUESTIONS

In its narrow sense, creativity refers to the abilities that are most characteristic of creative people. Creative abilities determine whether the individual has the power to exhibit creative behavior to a noteworthy degree. Whether or not the individual who has the requisite abilities will actually produce results of a creative nature will depend upon his motivational and temperamental traits. To the psychologist, the problem is as broad as the qualities that contribute significantly to creative productivity. In other words, the psychologist's problem is that of creative personality.

In defining personality, as well as other concepts preparatory to an investigation, definitions of an operational type are much to be preferred. I have often defined an individual's personality as his unique pattern of traits. A trait is any relatively enduring way in which persons differ from one another. The psychologist is particularly interested in those traits that are manifested in performance; in other words, in behavior traits. Behavior traits come under the broad categories of aptitudes, interests, attitudes, and temperamental qualities. By aptitude we ordinarily mean a person's readiness to learn to do certain types of things. There is no necessary implication in this statement as to the source of the degree of readiness. It could be brought about through hereditary determination or through environmental determination; usually, if not always, by an interaction of the two. By interest we usually mean the person's inclination or urge to engage in some type of activity. By attitude we mean his tendency to favor or not to favor (as shown objectively by approach-withdrawal behavior) some type of object or situation. Temperamental qualities describe a person's general emotional disposition: for example, his optimism, his moodiness, his self-confidence, or his nervousness.

Creative personality is then a matter of those patterns of traits that are characteristic of creative persons. A creative pattern is manifest in creative behavior, which includes such activities as inventing, designing, contriving, composing, and planning. People who exhibit these types of behavior to a marked degree are recognized as being creative.

There are certain aspects of creative genius that have aroused questions in the minds of those who have reflected much about the matter. Why is creative productivity a relatively infrequent phenomenon? Of all the people who have lived in historical times, it has been estimated that only about two in a million have become really distinguished (*5*). Why do so many geniuses spring from parents who are themselves very far from distinguished? Why is there so little apparent correlation between education and creative productiveness? Why do we not produce a larger number of creative geniuses than we do, under supposedly enlightened, modern educational practices? These are serious questions for thought and

[1] Address of the President of the American Psychological Association at Pennsylvania State College, September 5, 1950.

[2] A research project on the aptitudes of high-level personnel, supported by the Office of Naval Research.

- Sensitivity to problems
- Fluency
- Novelty
- Flexibility of mind
- Synthesis
- Reorganization
- Complexity
- Evaluation

The four P's model

- **Person:** qualities, abilities
- **Process:** mental functions, strategies, brainstorming
- **Product:** ideas, performances, songs, etc.
- **Press:** pressures; internal or external

Different types of c(reativity)

The two c's

- **Big C Creativity**
  - Eminence
  - World-class accomplishments
  - High-impact, culturally significant work
- **Little c creativity**
  - Everyday creativity
  - Hobbies, ideas, jokes, quips, actions
  - New for you, not for world at large

4-c's model

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Beyond Big and Little: The Four C Model of Creativity

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Most investigations of creativity tend to take one of two directions: everyday creativity (also called "little-c"), which can be found in nearly all people, and eminent creativity (also called "Big-C"), which is reserved for the great. In this paper, the authors propose a Four C model of creativity that expands this dichotomy. Specifically, the authors add the idea of "mini-c," creativity inherent in the learning process, and Pro-c, the developmental and effortful progression beyond little-c that represents professional-level expertise in any creative area. The authors include different transitions and gradations of these four dimensions of creativity, and then discuss advantages and examples of the Four C Model.

Keywords: creativity, everyday creativity, genius, creative development

Two separate events helped bring creativity to the forefront of psychology and the United States. One event took place at the 1950 meeting of the American Psychological Association, when Guilford (1950) used his presidential address to argue that the area of creativity was an understudied yet essential field. Creativity research, Guilford said, comprised only .2% of all psychological research; he challenged the field to increase this number. Although the impact of this talk can be easily overstated, Guilford's call to arms resonated with psychologists around the world (see, e.g., essays from most countries in *The International Handbook on Creativity*, J. Kaufman & Sternberg, 2006). A few years later, Russia launched the Sputnik satellite and triggered a great talent hunt in the United States that emphasized scientific ability, giftedness, and creativity (S. Kaufman & Sternberg, 2007).

In the decades that have followed, creativity research has continued at a solid pace. A quick PsycINFO search reveals that there have been more than 10,000 papers written about creativity in the last 10 years, across such diverse areas of psychology as cognitive, developmental, clinical, social, and industrial/organizational—and across such other fields as economics, education, and the arts (J. Kaufman & Sternberg, 2007). Creativity is seen as a desired quality for admissions to graduate school (Enright & Gitomer, 1989) and National Science Foundation grant applications (Lane, 1997). Moreover, creativity has been described as the most important economic resource of the 21st century (Florida, 2002). Yet the same broad spectrum that brings researchers together to study creativity across multiple disciplines has had some potentially negative effects. The exact question of *what is creativity* is often ignored or answered in too many different ways. For example, Plucker, Beghetto, and Dow (2004) selected 90 different articles with the word "creativity" in the title (60 from the two top creativity journals, and 30 from peer-reviewed business, education, and psychology journals). Of these papers, only 38% explicitly defined what creativity was. Further, basic questions about creativity's nature remain under debate. Is creativity a key part of positive psychology, or is it related to mental illness and other negative health outcomes? How does creativity relate to other, related constructs, such as personality and motivation? Can everyone be creative?

In this paper, we offer a preliminary, conceptual model to help frame these questions and more clearly articulate the nature of creativity. Currently, most investigations of creativity tend to take one of two directions. The first direction is a focus on eminent creativity. The goals are often to learn about creative genius and discuss which creative works may last forever (e.g., Simonton, 1994). Creative greatness may be studied by analyzing the lives of well-known creators, or interviewing renowned individuals, or by studying people who excel at high levels on creativity measures. These types of studies and theories are typically referred to as studying *Big-C* creativity. The other predominant thrust of work in the field looks more at everyday creativity (Richards, 1990), such as those creative activities in which the average person may participate each day (e.g., creatively arranging family photos in a scrapbook; combining left over Italian and Chinese food to make a tasty, new fusion of the two cuisines; or coming up with a creative solution to a complex scheduling problem at work). Most studies that use college students or children as participants focus on everyday creativity. The theories and studies along this line of thinking is usually said to focus on *little-c* creativity.

Dichotomies of this sort are found in many other fields. Historians, for example, sometimes concentrate on eminent historical figures, such as Taylor Branch (1988) did in his Pulitzer-Prize winning civil rights history, *Parting the Waters*, which is largely focused on Martin Luther King, Jr. Other writers, such as John Dittmer (1994) in *Local People*, which won the Bancroft Prize in American History, examine the same historical phenomena (as those taking the eminent individual approach) by focusing on important, but less well known, everyday people involved in grass-roots movements.

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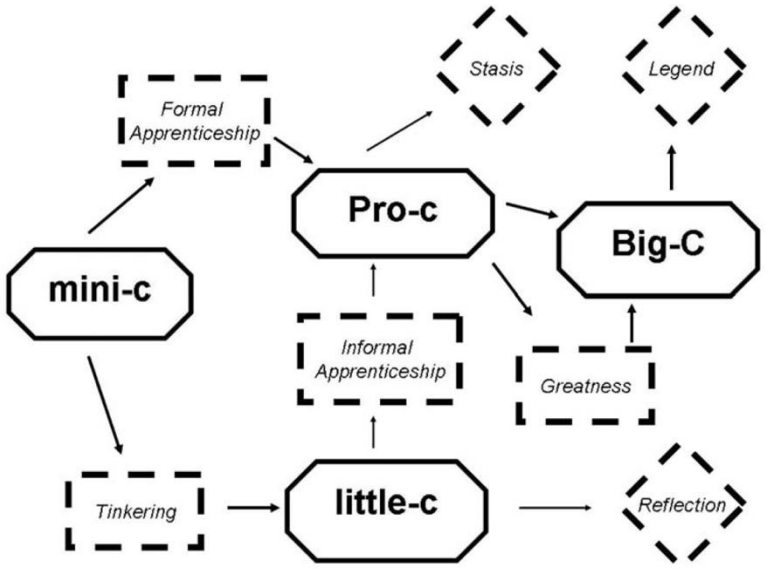
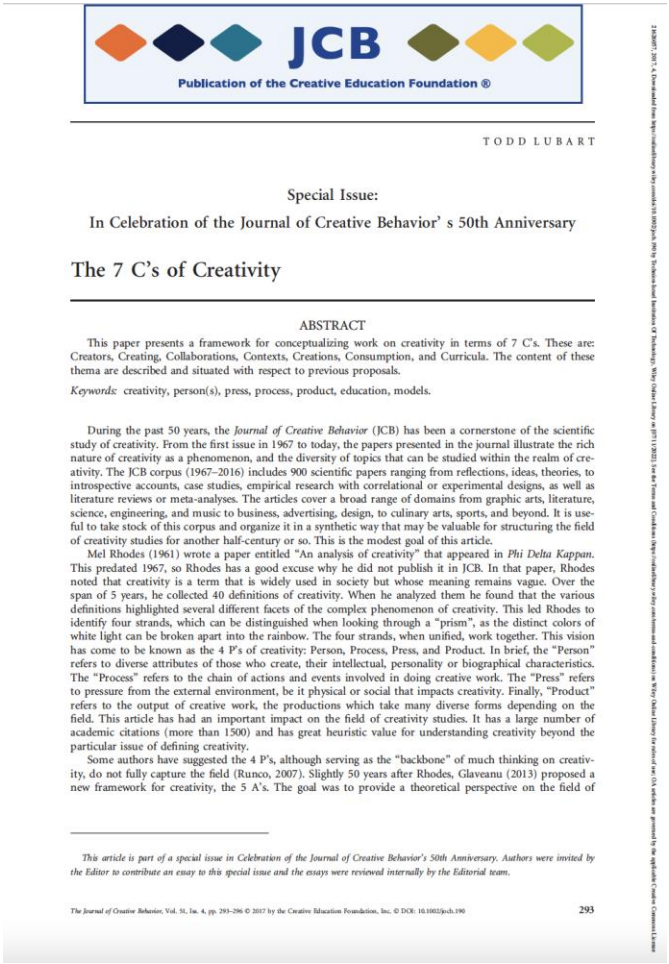


7-c's model



JCB
Publication of the Creative Education Foundation ®

TODD LUBART

Special Issue:
In Celebration of the Journal of Creative Behavior' s 50th Anniversary

The 7 C's of Creativity

ABSTRACT

This paper presents a framework for conceptualizing work on creativity in terms of 7 C's. These are: Creators, Creating, Collaborations, Contexts, Creations, Consumption, and Curricula. The content of these thema are described and situated with respect to previous proposals.

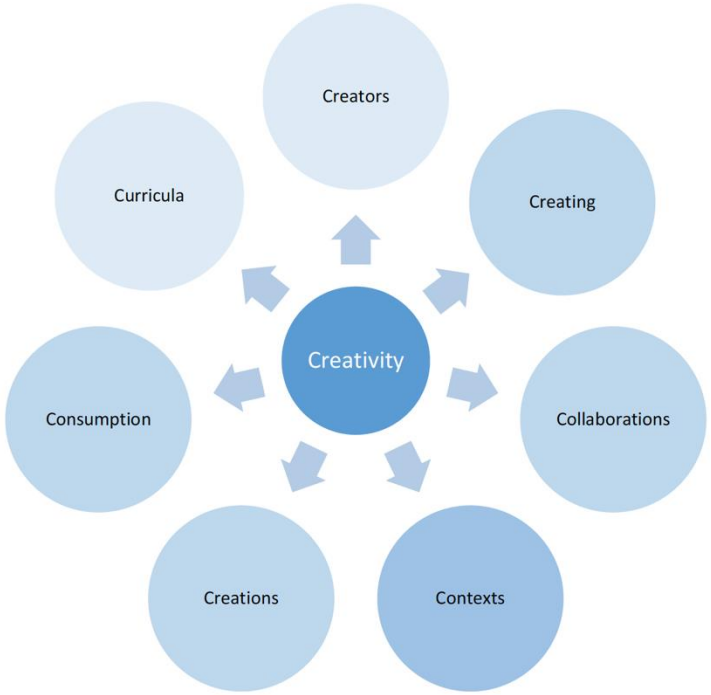
Keywords: creativity, person(s), press, process, product, education, models.

During the past 50 years, the *Journal of Creative Behavior* (JCB) has been a cornerstone of the scientific study of creativity. From the first issue in 1967 to today, the papers presented in the journal illustrate the rich nature of creativity as a phenomenon, and the diversity of topics that can be studied within the realm of creativity. The JCB corpus (1967–2016) includes 900 scientific papers ranging from reflections, ideas, theories, to introspective accounts, case studies, empirical research with correlational or experimental designs, as well as literature reviews or meta-analyses. The articles cover a broad range of domains from graphic arts, literature, science, engineering, and music to business, advertising, design, to culinary arts, sports, and beyond. It is useful to take stock of this corpus and organize it in a synthetic way that may be valuable for structuring the field of creativity studies for another half-century or so. This is the modest goal of this article.

Mel Rhodes (1961) wrote a paper entitled "An analysis of creativity" that appeared in *Phi Delta Kappan*. This predated 1967, so Rhodes has a good excuse why he did not publish it in JCB. In that paper, Rhodes noted that creativity is a term that is widely used in society but whose meaning remains vague. Over the span of 5 years, he collected 40 definitions of creativity. When he analyzed them he found that the various definitions highlighted several different facets of the complex phenomenon of creativity. This led Rhodes to identify four strands, which can be distinguished when looking through a "prism", as the distinct colors of white light can be broken apart into the rainbow. The four strands, when unified, work together. This vision has come to be known as the 4 P's of creativity: Person, Process, Press, and Product. In brief, the "Person" refers to diverse attributes of those who create, their intellectual, personality or biographical characteristics. The "Process" refers to the chain of actions and events involved in doing creative work. The "Press" refers to pressure from the external environment, be it physical or social that impacts creativity. Finally, "Product" refers to the output of creative work, the productions which take many diverse forms depending on the field. This article has had an important impact on the field of creativity studies. It has a large number of academic citations (more than 1500) and has great heuristic value for understanding creativity beyond the particular issue of defining creativity.

Some authors have suggested the 4 P's, although serving as the "backbone" of much thinking on creativity, do not fully capture the field (Runco, 2007). Slightly 50 years after Rhodes, Glaveanu (2013) proposed a new framework for creativity, the 5 A's. The goal was to provide a theoretical perspective on the field of

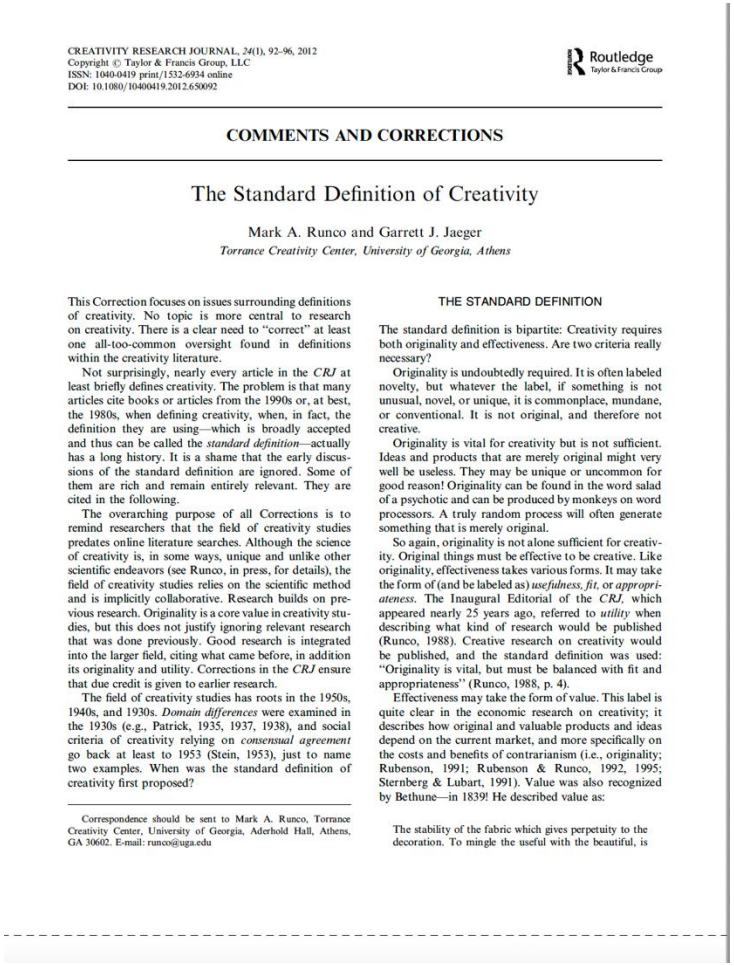
This article is part of a special issue in Celebration of the Journal of Creative Behavior's 50th Anniversary. Authors were invited by the Editor to contribute an essay to this special issue and the essays were reviewed internally by the Editorial team.



Dimensions of creativity (product)

Novelty & appropriateness

- The "**standard**" definition: novel and useful
- **Novel**: original, unique, unusual compared to others, statistically rare
- **Useful**: appropriate, workable, effective, satisfying, adaptive *in context*



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COMMENTS AND CORRECTIONS

The Standard Definition of Creativity

Mark A. Runco and Garrett J. Jaeger
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This Correction focuses on issues surrounding definitions of creativity. No topic is more central to research on creativity. There is a clear need to "correct" at least one all-too-common oversight found in definitions within the creativity literature.

Not surprisingly, nearly every article in the *CRJ* at least briefly defines creativity. The problem is that many articles cite books or articles from the 1990s or, at best, the 1980s, when defining creativity, when, in fact, the definition they are using—which is broadly accepted and thus can be called the *standard definition*—actually has a long history. It is a shame that the early discussions of the standard definition are ignored. Some of them are rich and remain entirely relevant. They are cited in the following.

The overarching purpose of all Corrections is to remind researchers that the field of creativity studies predates online literature searches. Although the science of creativity is, in some ways, unique and unlike other scientific endeavors (see Runco, in press, for details), the field of creativity studies relies on the scientific method and is implicitly collaborative. Research builds on previous research. Originality is a core value in creativity studies, but this does not justify ignoring relevant research that was done previously. Good research is integrated into the larger field, citing what came before, in addition its originality and utility. Corrections in the *CRJ* ensure that due credit is given to earlier research.

The field of creativity studies has roots in the 1950s, 1940s, and 1930s. *Domain differences* were examined in the 1930s (e.g., Patrick, 1935, 1937, 1938), and social criteria of creativity relying on *consensual agreement* go back at least to 1953 (Stein, 1953), just to name two examples. When was the standard definition of creativity first proposed?

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THE STANDARD DEFINITION

The standard definition is bipartite: Creativity requires both originality and effectiveness. Are two criteria really necessary?

Originality is undoubtedly required. It is often labeled novelty, but whatever the label, if something is not unusual, novel, or unique, it is commonplace, mundane, or conventional. It is not original, and therefore not creative.

Originality is vital for creativity but is not sufficient. Ideas and products that are merely original might very well be useless. They may be unique or uncommon for good reason! Originality can be found in the word salad of a psychotic and can be produced by monkeys on word processors. A truly random process will often generate something that is merely original.

So again, originality is not alone sufficient for creativity. Original things must be effective to be creative. Like originality, effectiveness takes various forms. It may take the form of (and be labeled as) *usefulness, fit,* or *appropriateness.* The Inaugural Editorial of the *CRJ,* which appeared nearly 25 years ago, referred to *utility* when describing what kind of research would be published (Runco, 1988). Creative research on creativity would be published, and the standard definition was used: "Originality is vital, but must be balanced with fit and appropriateness" (Runco, 1988, p. 4).

Effectiveness may take the form of value. This label is quite clear in the economic research on creativity; it describes how original and valuable products and ideas depend on the current market, and more specifically on the costs and benefits of contrarianism (i.e., originality; Rubenson, 1991; Rubenson & Runco, 1992, 1995; Sternberg & Lubart, 1991). Value was also recognized by Bethune—in 1839! He described value as:

> The stability of the fabric which gives perpetuity to the decoration. To mingle the useful with the beautiful, is

Novelty without usefulness

- Is too **much novelty** a bad thing?
- **Schizophrenic** patients are known for extraordinary **novelty** (free associations)
- Many ideas lack **practicality**/appropriateness
- Illustrates the **usefulness of usefulness** in defining creativity

Appropriateness

- Appropriateness depends on the domain
- Painting vs. scientific discovery
- Cultures differ in their **values** (e.g. clothing)
- **Valuable** does not always mean **positive** (e.g., Bernie Madoff)

Surprisingness

- Is **surprise** different than **novelty**?

- Surprise is **emotional**, novelty is less so

But..

- Is that it?
- Are we missing anything?
- The process definition of creativity

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Check for updates

The Process Definition of Creativity

Adam E. Green[a], Roger E. Beaty[b], Yoed N. Kenett[c], and James C. Kaufman[d]

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ABSTRACT

The "standard" definition of creativity as novel and useful describes creative products, but creativity is constituted by processes. This misalignment contributes to the oft-noted challenges of operationalizing creativity. Here, we distinguish creativity as a process from creativity as an attribute (i.e. "creative-ness"). Operating from *a priori* premises of creativity theory, we develop a process definition of creativity. Specifically, creativity is defined as internal attention constrained by a generative goal. This definition comprises three criteria: 1) attention is directed internally (toward mental representations); 2) attentional operations (e.g. search, manipulation) are constrained to fit parameters of a to-be-achieved goal state (whether or not a goal is actually achieved); and 3) the goal state is generative (not already precisely held in memory). We illustrate how these three definitional process elements align with insights yielded by creativity neuroscience, clarify ontological distinctions (e.g. from mind-wandering and retrieval), and relate the process definition to process-based models. The process definition provides minimal necessity and sufficiency criteria for whether a process should be considered creativity, but does not exclude the many other perceptual, emotional, etc. elements that can contribute to creativity processes. Researchers should specify whether they are studying creativity-as-process vs. "creative-ness," and consider including process-focused assessments.

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Creativity has perhaps never been more universally espoused as a virtue across wide-ranging sectors of the academy, as well as in education, arts, and industry than it is at the present moment. The science of creativity is receiving increased investment, and creativity researchers are developing exciting new methods for both observation and enhancement of creative cognition. However, it is the most fundamental question about creativity – the definitional question – that has persistently clouded scientific progress. Both the timely and timeless importance of creativity make advancing the mechanistic understanding of creativity, especially as a process that can be taught and enhanced, a scientific priority. The answer to the question, "what is creativity?" should provide a meaningful framework for research aimed at understanding how creativity works. In plain terms, if we hope to effectively research and understand creativity as a process, we need to first define it as a process.

Building on the rich history of theoretical development in creativity, from Guilford (1950) to Stein (1953) to Hennessey and Amabile (2010) to Simonton (2012), Runco and Jaeger (2012) presented, "A Standard Definition of Creativity," twelve years ago in CRJ, highlighting the criteria of originality and effectiveness. This definition, henceforth referred to as "the product definition," provides a concise description of the attributes that make for a successful creative product. Because the terms, novelty and usefulness, appear to be most frequently used in the literature to convey the product-focused definition of creativity that has emerged from historical and more recent theoretical developments, we will primarily use those terms here, though we note that other terms such as effectiveness, value, meaningfulness, etc. can be used instead with subtly different implications. The product definition has been extremely valuable for galvanizing the field around standards for assessing creative products. However, there remains a widely-appreciated need for greater theoretical specificity in operationalizing the construct of creativity (Kaufman & Glăveanu, 2021). As we will argue below, the lack of clarity may be due in large part to a linguistic ambiguity in the word, creativity, itself. A bit of linguistic bad luck has led to a general conflation of different constructs conveyed by different uses of the word that instead should be understood as having different definitions, including a conflation of creativity as the attribute of a product with creativity as a process. While creativity as the attribute of a product is defined

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The creative process

The creative process (Wallas, 1926)

- Preparation
  - preparatory work on a problem that focuses the individual's mind on the problem and explores the problem's dimensions
- Incubation
  - where the problem is internalized into the unconscious mind and nothing appears externally to be happening
- Intimation
  - the creative person gets a 'feeling' that a solution is on its way
- Illumination
  - where the creative idea bursts forth from its preconscious processing into conscious awareness
- Verification
  - where the idea is consciously verified, elaborated, and then applied

A short detour

Trends in
Cognitive Sciences

CellPress

Opinion

Creative problem solving in knowledge-rich contexts

Wenjing Yang,[1,2,5] Adam E. Green,[3,5] Qunlin Chen,[1,2] Yoed N. Kenett,[4] Jiangzhou Sun,[1,2] Dongtao Wei,[1,2] and Jiang Qiu[1,2,*]

Creative problem solving (CPS) in real-world contexts often relies on reorganization of existing knowledge to serve new, problem-relevant functions. However, classic creativity paradigms that minimize knowledge content are generally used to investigate creativity, including CPS. We argue that CPS research should expand consideration of knowledge-rich problem contexts, both in novices and experts within specific domains. In particular, paradigms focusing on creative analogical transfer of knowledge may reflect CPS skills that are applicable to real-world problem solving. Such paradigms have begun to provide process-level insights into cognitive and neural characteristics of knowledge-rich CPS and point to multiple avenues for fruitfully expanding inquiry into the role of crystalized knowledge in creativity.

Highlights

Creative problem solving (CPS) relies on the reorganization of existing knowledge to serve new, problem-relevant functions.

Extant creativity research, especially brain-based research, largely does not reflect the knowledge-rich contexts in which the application of previously-acquired knowledge is critical, as is frequently the case in real-world CPS.

Knowledge-rich CPS frequently involves expertise, and can be fruitfully studied in expert participants. It can also be studied in novices when content knowledge is available as a component of the experimental paradigm.

Behavioral and neuroimaging CPS paradigms based on analogical transfer can provide process-level insights into knowledge-rich CPS in non-experts. The transfer-based heuristic prototype paradigm has the potential to be flexibly applied across diverse domains of knowledge.

Better understanding of CPS as a process, especially via analogical transfer, has timely potential to inform education and creativity training.

Real-world CPS requires crystalized knowledge

The extraordinary capacity of humans to generate creative solutions to problems, which was first essential to our competition with other species, has taken on renewed interest as we enter a new phase of competition (and collaboration) with 'thinking' machines. While as many as 50% of current jobs in the USA are projected to become obsolete in the next two decades, substantial growth is projected in creative sectors [1]. As interest in CPS has increased among researchers and educators, as well as in industry, CPS has been primarily operationalized via knowledge-lean measures of creativity [2–5] that seek to minimize or eliminate the requirement of specific knowledge content for creative performance. In the classical creativity task, the **alternative uses task (AUT)** (see Glossary), for example, participants are evaluated on their capacity to originate divergent ideas (e.g., grinding up a brick to use as fairy dust in a costume), as opposed to their ability to apply knowledge transferred from other contexts. Another commonly used assessment, the figural Torrance Test of Creative Thinking (TTCT), requires participants to use a given shape/figure (e.g., a teardrop shape) as a basis to create their own figure. As with the AUT, generating novel figures emphasizes origination over the application of **crystalized knowledge**. By contrast, the real-world value of CPS – including in the growing creative sectors of the innovation economy – is almost always in knowledge-rich contexts in which knowledge acquired through prior learning (e.g., education and life experience) across multiple domains can be flexibly applied to solve novel problems. In other words, real creative solutions frequently require the use of knowledge, which is not required – and is indeed deliberately avoided – in standard creativity measures.

Models of creative thinking stress the importance of knowledge to creativity [6–9]. Knowledge provides a basis for interpreting new information. Moreover, previously acquired knowledge must be recombined and reorganized to produce the new knowledge that allows the generation of novel ideas [10]. Empirically based observations have suggested that, after controlling for some

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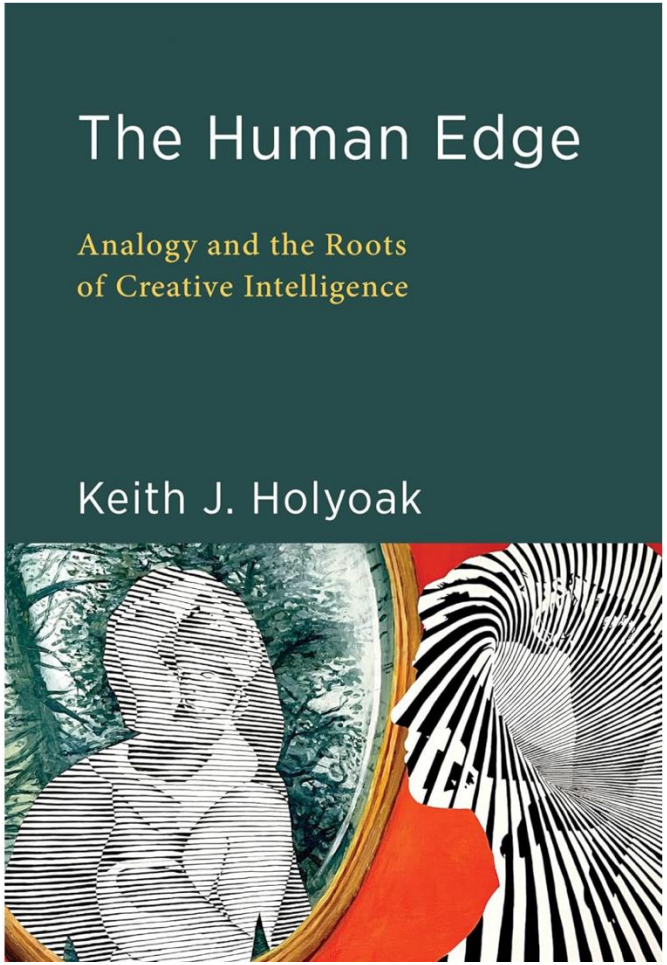
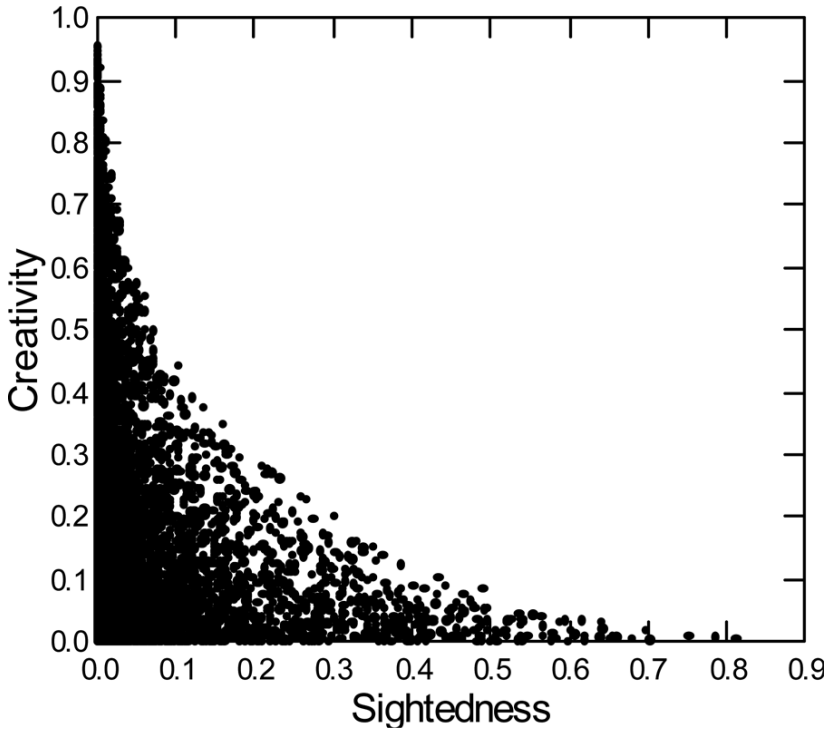
[4]Faculty of Industrial Engineering and Management, Technion–Israel Institute of Technology, Haifa, Israel



Creativity as blind variation and selective retention (BVSR) – Dean Simonton



Journal of Theoretical and Philosophical Psychology
2013, Vol. 33, No. 4, 253–266

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Creative Thought as Blind Variation and Selective Retention: Why Creativity is Inversely Related to Sightedness

Dean Keith Simonton
University of California, Davis

Campbell (1960) proposed the theory that creativity required blind variation and selective retention (BVSR). More than a half century has transpired without any resolution of the controversy over the theory's validity. This inability to reach consensus may reflect a fundamental failure on both sides to define the critical terms of the debate, namely, creativity and blindness. Hence, to help resolve the issue, the ideas making up a variant set are first described via three parameters: (a) the idea's initial probability of generation, (b) its final utility, and (c) any prior knowledge of its utility value. These three subjective parameters are then used to derive a *creativity index* applicable to each idea in the set. The same parameters are also deployed to produce a *sightedness metric* that describes the sightedness of the variant set as well as each idea in that set. It is then logically demonstrated, first, that an idea's creativity is inversely related to its sightedness, and, second, that an idea's creativity is inversely related to the sightedness of the variant set that contains that idea. Furthermore, the same general conclusions hold when the third parameter is omitted from the two definitions or when the two definitions are not functions of identical parameters (e.g., novelty in one but originality in the other). Because blindness is just the inverse of sightedness, it automatically follows that creativity has an essential positive connection with blind variation. The article closes with a discussion of BVSR implications regarding the joint distribution of creativity and sightedness.

Keywords: creativity, sightedness, blindness, BVSR

Although creativity has often been seen to be a neglected topic in psychology (Guilford, 1950; Sternberg & Lubart, 1996), the subject has experienced an exceptional influx of interest over the past dozen years or so (for recent reviews, see Hennessey & Amabile, 2010; Runco, 2004). Indeed, creativity research now attracts psychological research from multiple subdisciplines, including the cognitive neurosciences, differential and personality, life span development, and social. That increased attention is not without its costs. Alternative theories, measures, and methods have proliferated almost without bounds, introducing numerous controversies. One of these persistent debates concerns whether creativity is generic or domain specific (Simonton, 2007b; Sternberg, 2005). Is there a single "creative process" (or set of processes) that operates in all domains, whether artistic, scientific, or technological? Or is creativity so contingent on domain-specific expertise that artists, scientists, or inventors all create in very different ways? Should domain-specificity be the norm, then psychologies of creativity would have to be as numerous as domains of creativity, a possibility that must seriously complicate research—and might even render psychology irrelevant as an explanatory perspective. Relative to any creativity researcher, poets would know appreciably more about how to create poetry, and physicists know more about how to be creative in physics.

A potential solution to this problem might have been provided by Donald T. Campbell (1960) over a half century ago (Simonton, 2011b). In particular, Campbell argued that all creativity depends on the two-step procedure of blind variation and selective retention, or "BVSR." Of these two steps, the first is the most

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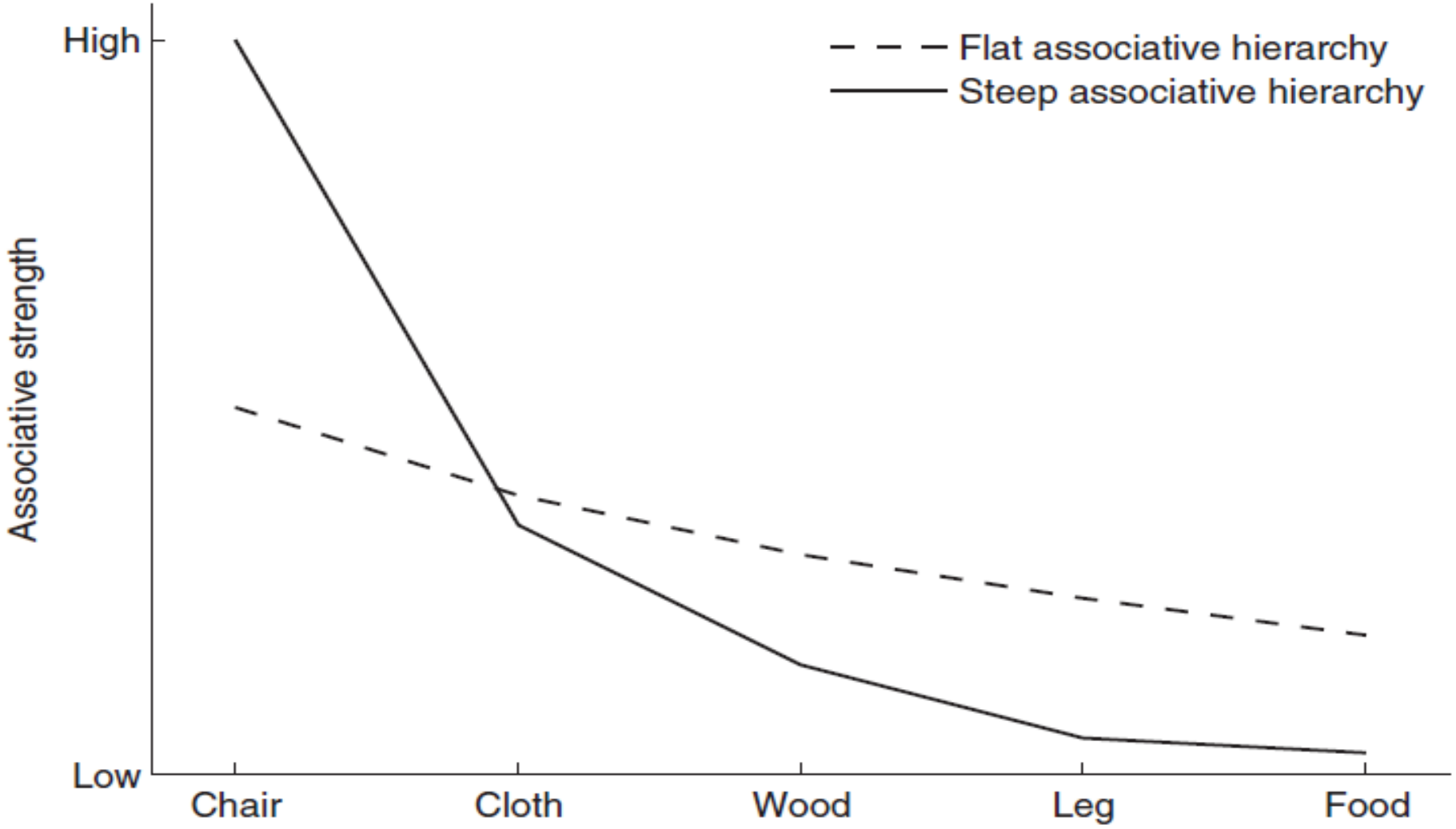
The associative theory of creativity (Mednick, 1962)



Creative process model

JCB
Publication of the Creative Education Foundation ®

MICHAEL D. MUMFORD
TRISTAN MCINTOSH

Special Issue:
In Celebration of the Journal of Creative Behavior's 50th Anniversary

Creative Thinking Processes: The Past and the Future

ABSTRACT

For more than one hundred years, students of creativity, including seminal efforts published in the *Journal of Creative Behavior*, have sought to identify the key processes people must execute to produce creative problem solutions. In recent years, we have seen a consensual model of key creative thinking processes being accepted by the field. In the present effort, we review the evidence bearing on the eight core processes proposed in this consensual model. Subsequently, directions for future research on creative thinking processes are discussed.

Keywords: creativity, creative thinking, processes, cognition, knowledge.

The many, and varied, influences on creative performance broaches a fundamental question (Mumford, Hunter, & Byrne, 2009). What is the basis for peoples' production of creative problem solutions? In fact, over the years, the *Journal of Creative Behavior* has published a number of articles which hoped to provide an answer to this question (e.g., Isaksen & Treffinger, 2004; Parnes & Biondi, 1975). As Parnes and Noller (1972) pointed out, the answers we provide to this question influence not only theory (Weisberg & Hass, 2007) but also how we seek to develop (Scott, Leritz, & Mumford, 2004), assess (Vessey & Mumford, 2012), and manage (Mumford, Martin, Elliott, & McIntosh, in press) creative people.

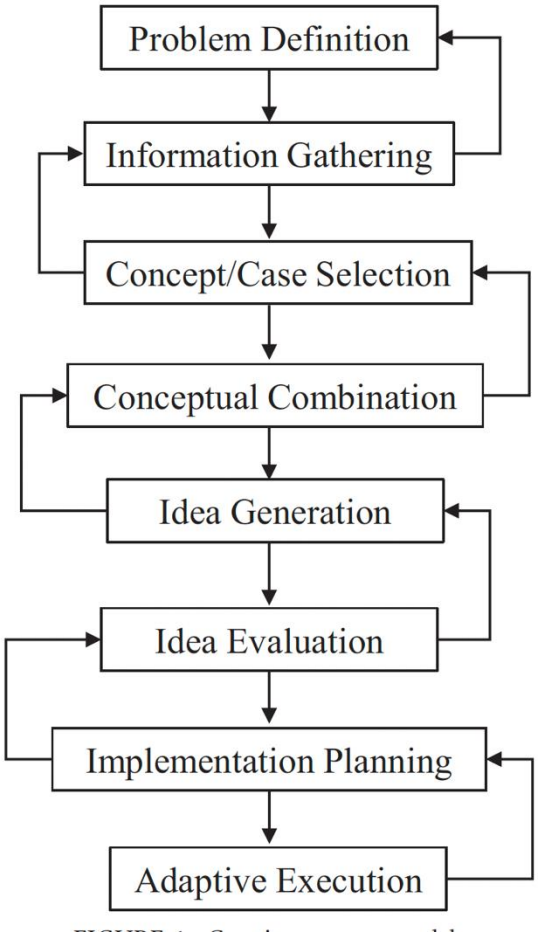
One approach that has been used to answer this question is identification of the cognitive processes people must execute to produce creative problem solutions. And, over the years, a number of models describing peoples' creative thinking processes have been proposed (e.g. Dewey, 1910; Sternberg, 1986). In recent years, however, the model proposed by Mumford, Mobley, Reiter-Palmon, Uhlman, and Doares (1991) has become the standard by which we understand the key processing operations needed for creative thought. In the present effort, we will examine past work bearing on this model and its implications for future work on creative problem solving.

THE PAST

Mumford et al.' (1991) model was based on three assumptions: (a) creative problem solving requires the production of high quality, original, and elegant solutions to complex, novel, ill-defined problems, (b) problem solving requires knowledge or expertise, and (c) although different performance domains impose different knowledge requirements, and stress, weight, processes differently, similar processes would underlie creative thought in most domains of endeavor. These observations, coupled with a review of prior studies, led Mumford et al. (1991) to propose the eight process model presented in Figure 1.

Because creative problems are novel, complex, and ill-defined, it is held that creative problem solving begins with problem definition. Problem definition provides the basis for information gathering which, in

This article is part of a special issue in Celebration of the Journal of Creative Behavior's 50th Anniversary. Authors were invited by the Editor to contribute an essay to this special issue and the essays were reviewed internally by the Editorial team.



Deconstructing the creative process

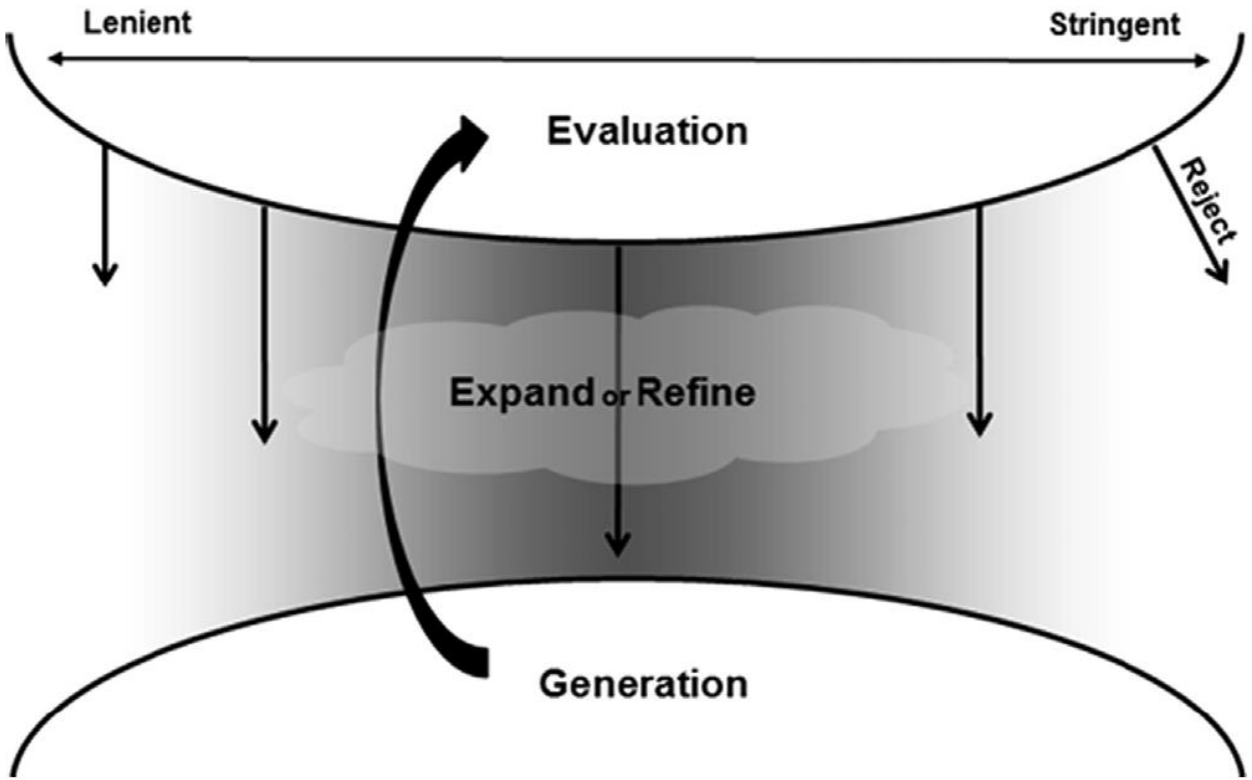
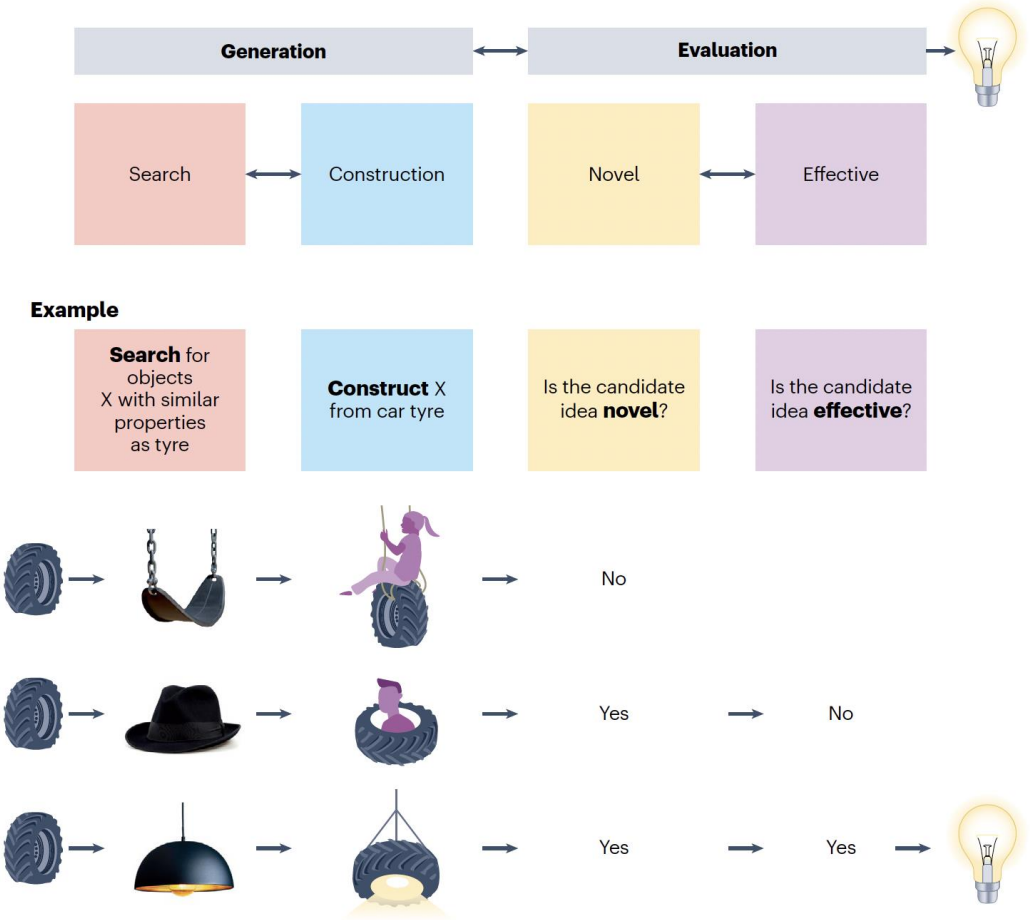


Fig. 1. Dual-model of creativity.

Mayseless, Aharon-Peretz, & Shamay-Tsoory (2014). *Neuropsychologia*, 64, 157-165.

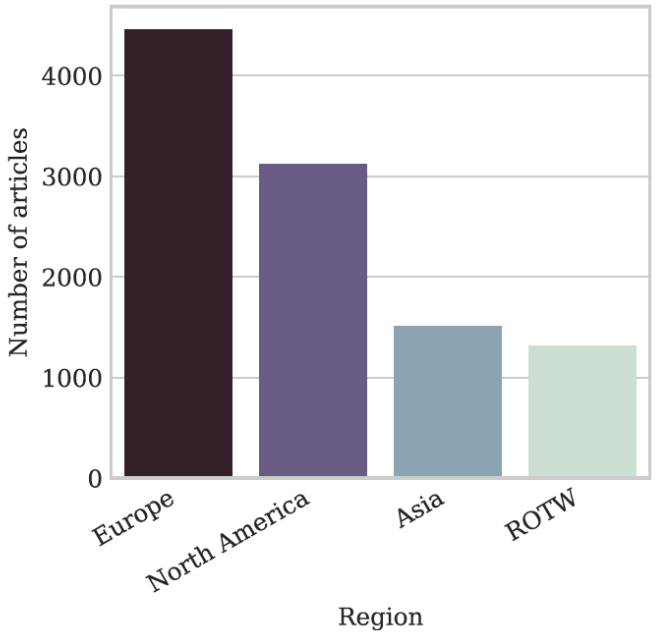
The role of memory in creative ideation (MemIC)

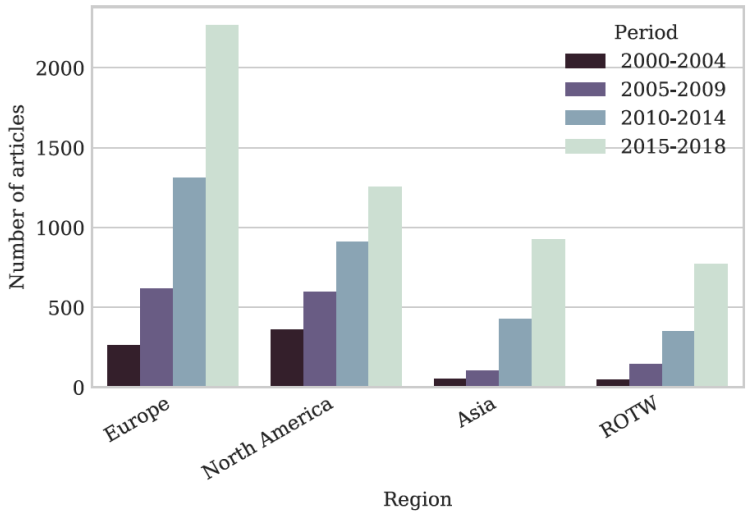


Benedek, Beaty, Schacter, & Kenett (2023). *Nature Reviews Psychology*, 2(4), 246-257.

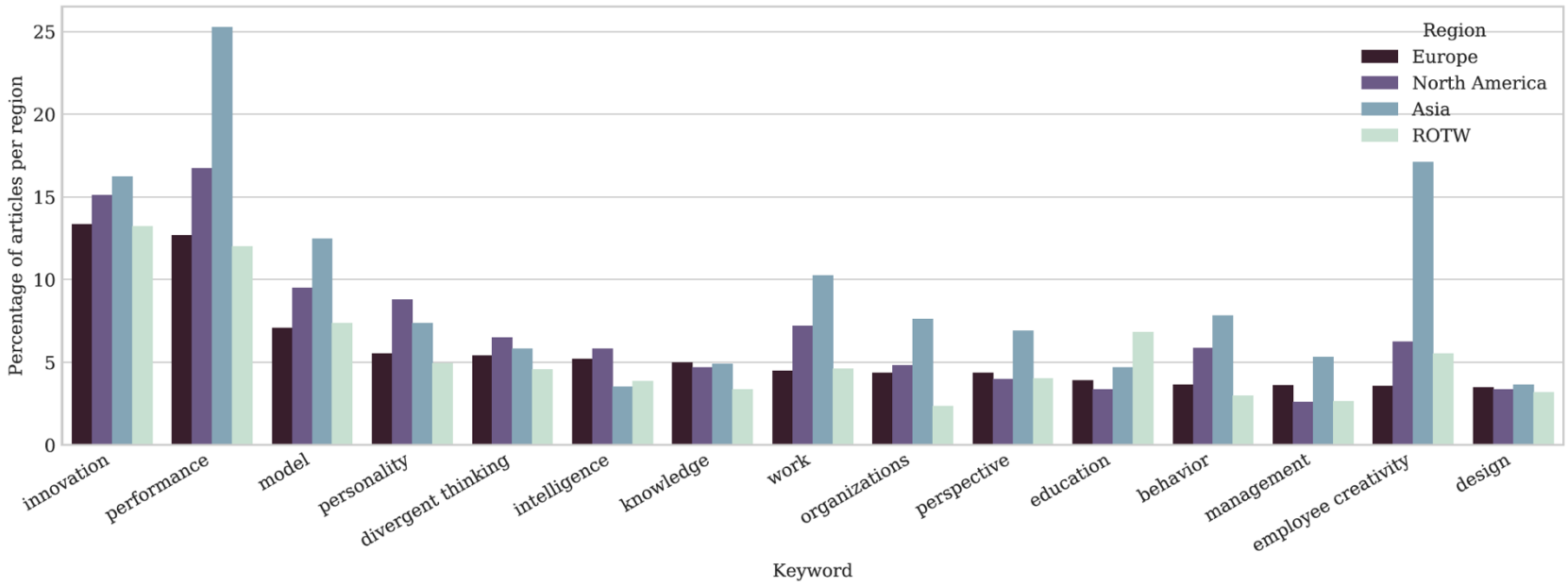
Creativity research

Creativity around the world

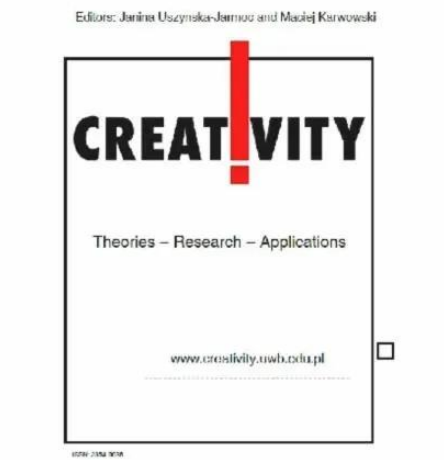


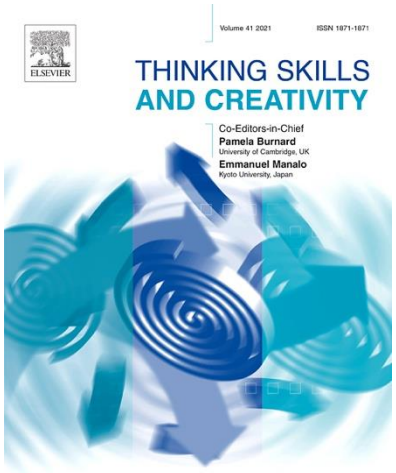


Top 15 keywords

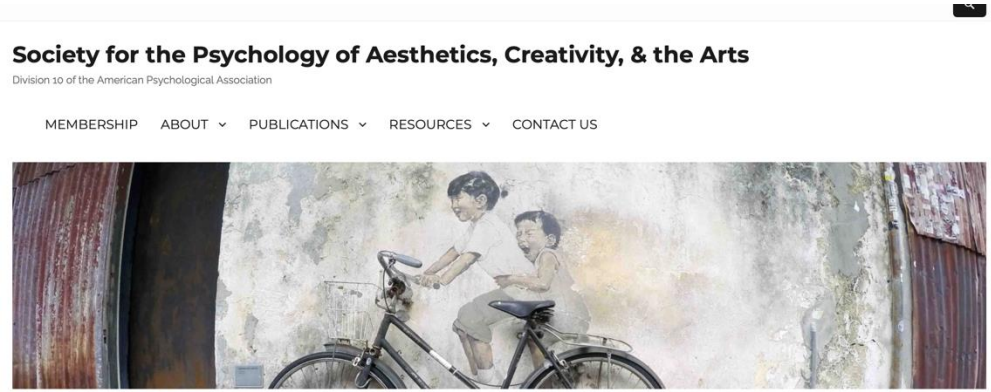


Creativity journals





Creativity societies

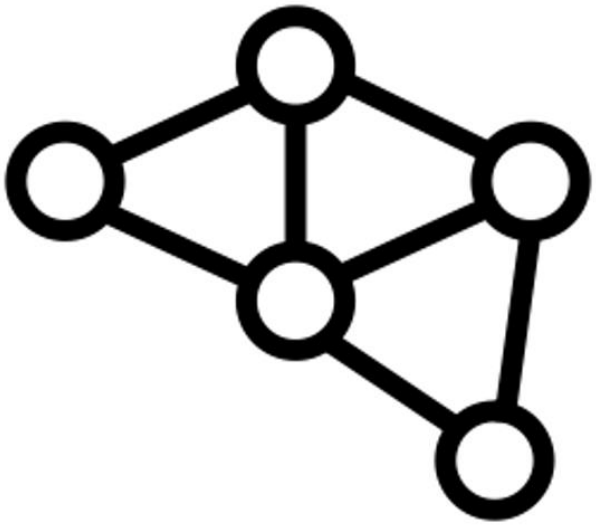


The role of knowledge in creativity

The role of memory in creativity?

A short demonstration

How do we search our memory?



Map/space/
network

Vehicle/
process

Research questions

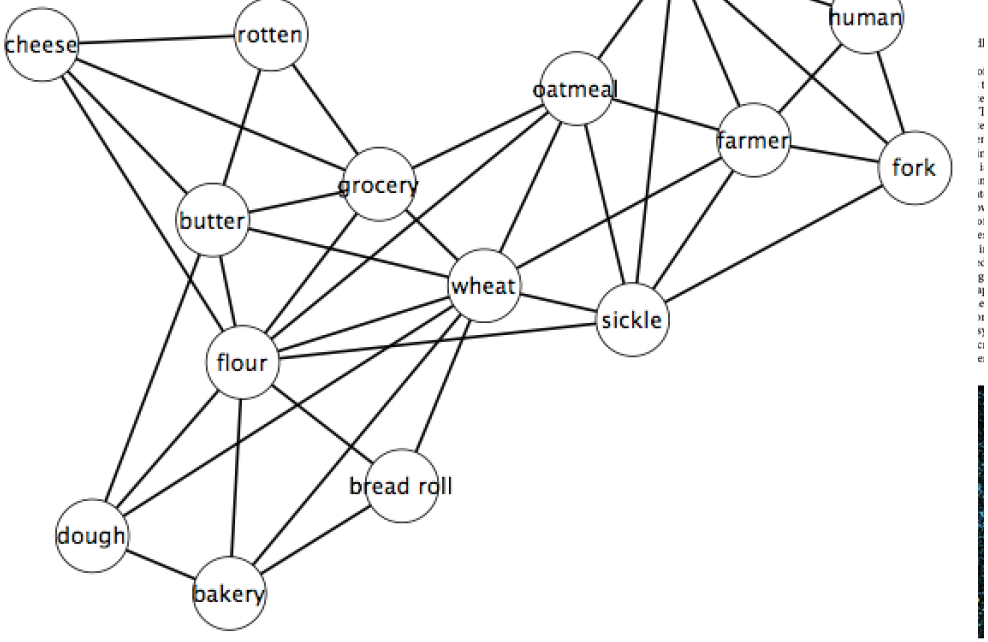
Cognitive

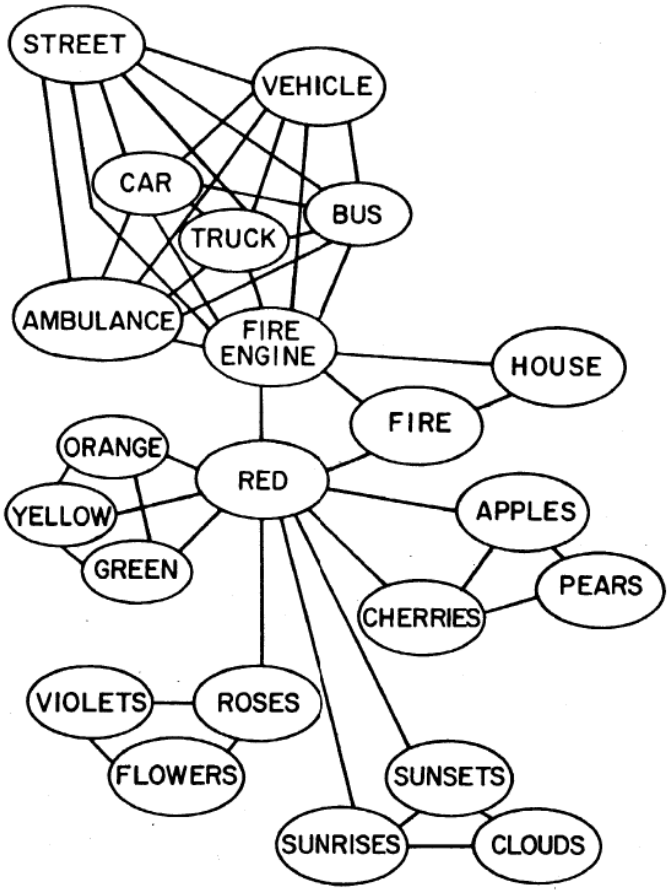
- What is the role of knowledge in creative thinking?
- What are the cognitive dynamics involved in the creative process?

Neural

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

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)

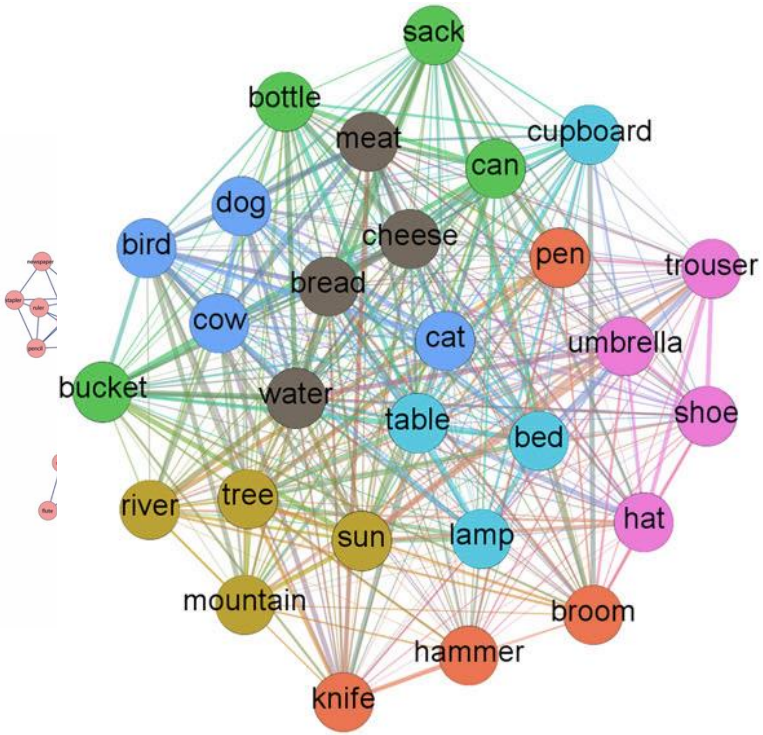
Collins and Loftus (1975)

The role of knowledge in creative thinking

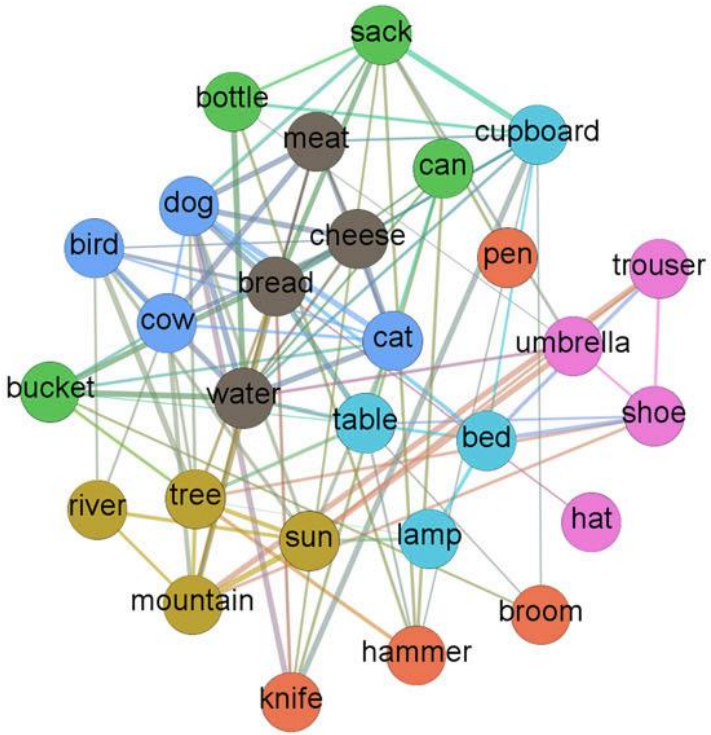
Structure

Dynamics

Young people



High creative



Low creative

Kenett et al. (2017). *Thinking & Reasoning*, *23*(4), 271–299.

Kenett et al. (2014). *Frontiers in Human Neuroscience*, *8*, 407.

The plot thickens

THINKING & REASONING
https://doi.org/10.1080/13546783.2022.2076742

Routledge
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Check for updates

Semantic memory and creativity: the costs and benefits of semantic memory structure in generating original ideas

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[a]Department of Psychology, Pennsylvania State University, University Park, PA, USA; [b]Faculty of Industrial Engineering and Management, Technion—Israel Institute of Technology, Israel; [c]Jefferson Center for Interprofessional Practice and Education, Thomas Jefferson University, Philadelphia, PA, USA; [d]Department of Psychology, Harvard University, Cambridge, MA, USA

ABSTRACT

Despite its theoretical importance, little is known about how semantic memory structure facilitates and constrains creative idea generation. We examine whether the semantic richness of a concept has both benefits and costs to creative idea generation. Specifically, we tested whether cue set size—an index of semantic richness reflecting the average number of elements associated with a given concept—impacts the quantity (fluency) and quality (originality) of responses generated during the Alternate Uses Task (AUT). Across four studies, we show that low-association, sparse, AUT cues benefit originality at the cost of fluency compared to high-association, rich, AUT cues. Furthermore, we found an interaction with individual differences in fluid intelligence in the low-association AUT cues, suggesting that constraints of sparse semantic knowledge can be overcome with top-down intervention. Our findings indicate that semantic richness differentially impacts the quality and quantity of generated ideas, and that cognitive control processes can facilitate idea production when conceptual knowledge is limited.

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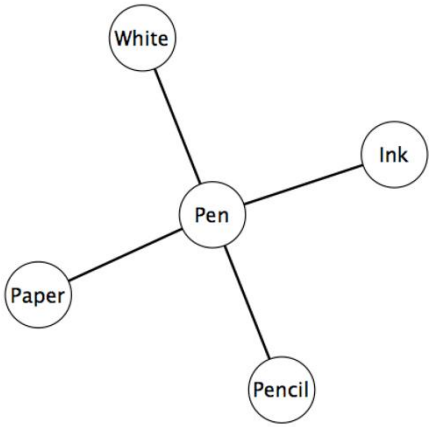
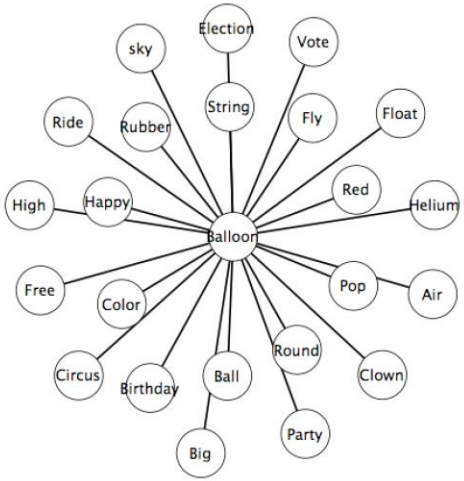
KEYWORDS Creativity; divergent thinking; fluid intelligence; semantic memory; Cue set size

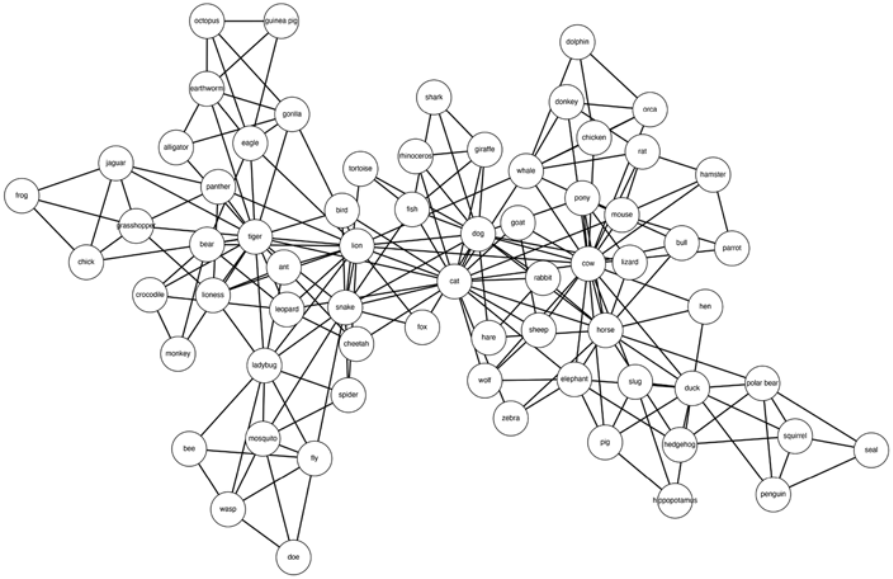
Low-Cue



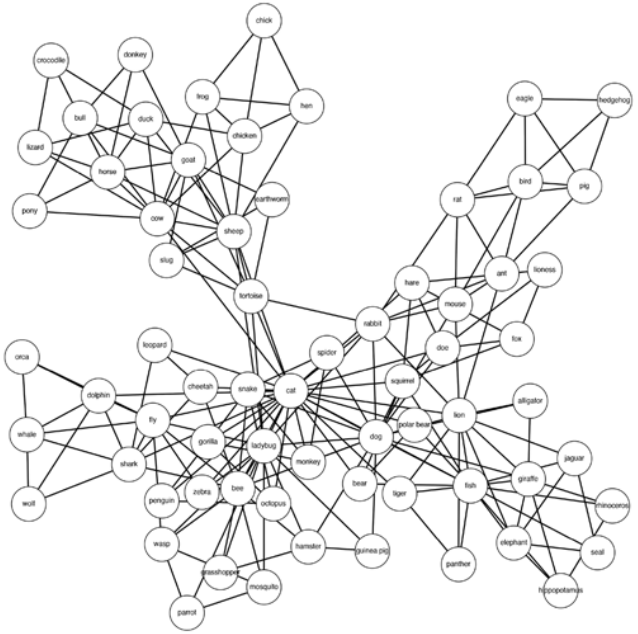
High-Cue



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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* Correspondence: skl5875@psu.edu (S.A.L.); rebeaty@psu.edu (R.E.B.)

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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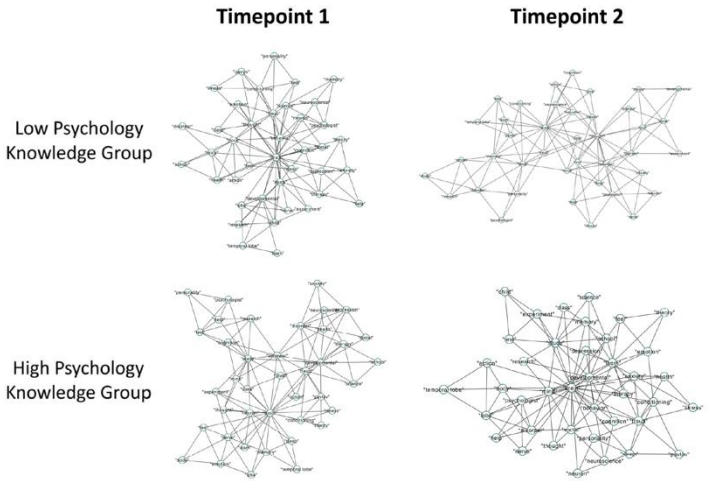
1. Introduction

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



Old people

Cognition 211 (2021) 104631

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Quantifying flexibility in thought: The resiliency of semantic networks differs across the lifespan

Abigail L. Cosgrove [a], Yoed N. Kenett [b], Roger E. Beaty [a], Michele T. Diaz [a,*]

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Cognition
Verbal fluency

ABSTRACT

Older adults tend to have a broader vocabulary compared to younger adults – indicating a richer storage of semantic knowledge – but their retrieval abilities decline with age. Recent advances in quantitative methods based on network science have investigated the effect of aging on semantic memory structure. However, it is yet to be determined how this aging effect on semantic memory structure relates to its overall flexibility. Percolation analysis provides a quantitative measure of the flexibility of a semantic network, by examining how a semantic memory network is resistant to "attacks" or breaking apart. In this study, we incorporated percolation analyses to examine how semantic networks of younger and older adults break apart to investigate potential age-related differences in language production. We applied the percolation analysis to 3 independent sets of data (total N = 78 younger, 78 older adults) from which we generated semantic networks based on verbal fluency performance. Across all 3 datasets, the percolation integrals of the younger adults were larger than older adults, indicating that older adults' semantic networks were less flexible and broke down faster than the younger adults'. Our findings provide quantitative evidence for diminished flexibility in older adults' semantic networks, despite the stability of semantic knowledge across the lifespan. This may be one contributing factor to age-related differences in language production.

1. Introduction

Aging is associated with cognitive decline, and this decline is seen in a number of areas of cognition, such as speed, inhibition, and language production. Older adults need to adapt to these age-related deficits to better navigate everyday tasks – yet as individuals age, they tend to become less flexible and have increased difficulty adapting to new environments (i.e., declines in processing speed and cognitive control; Hasher, Lustig, & Zacks, 2008; Salthouse, 2010). In contrast, one ability that remains remarkably stable across the lifespan is semantic knowledge or semantic memory (e.g., Park et al., 2002). However, semantic abilities are most often measured through vocabulary, and vocabulary inventories are typically un-timed, possibly minimizing age-related differences. Moreover, vocabulary inventories only assess knowledge of a relatively small sample of words, vastly underestimating the depth, breadth, and complexity of semantic knowledge. Words and their semantic features have structure and inter-relations among them (e.g., they can be represented as networks; Siew, Wulff, Beckage, & Kenett, 2019), which vocabulary inventories cannot capture. In the current study, we quantitatively examine, for the first time, the effect of aging on flexible thinking, by applying computational methods to estimate the *flexibility of* semantic memory structure of younger and older adults across three different samples. Specifically, we apply network science methods to estimate the semantic networks of these samples and examine the flexibility via a percolation analysis, which measures network resilience, or flexibility, by the process in which it breaks apart (Kenett et al., 2018), to further assess age-related decline.

2. Aging, flexibility, and semantic memory

Compared to the content of semantic knowledge, the structure of semantic knowledge may be even more relevant in aging, as older adults tend to have an equal or broader vocabulary compared to younger adults, indicating a richer storage of semantic knowledge (Kavé & Halamish, 2015; Kemper & Sumner, 2001; Park et al., 2002; Verhaeghen, 2003). Indeed, older adults show comparable performance to younger adults in a variety of semantic measures, including generating word associations (Bowles, Williams, & Poon, 1983; Burke & Peters,

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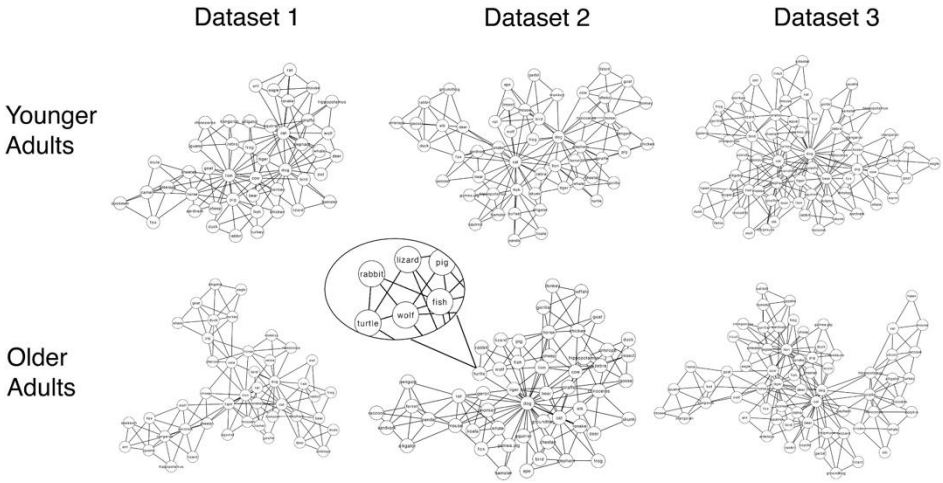
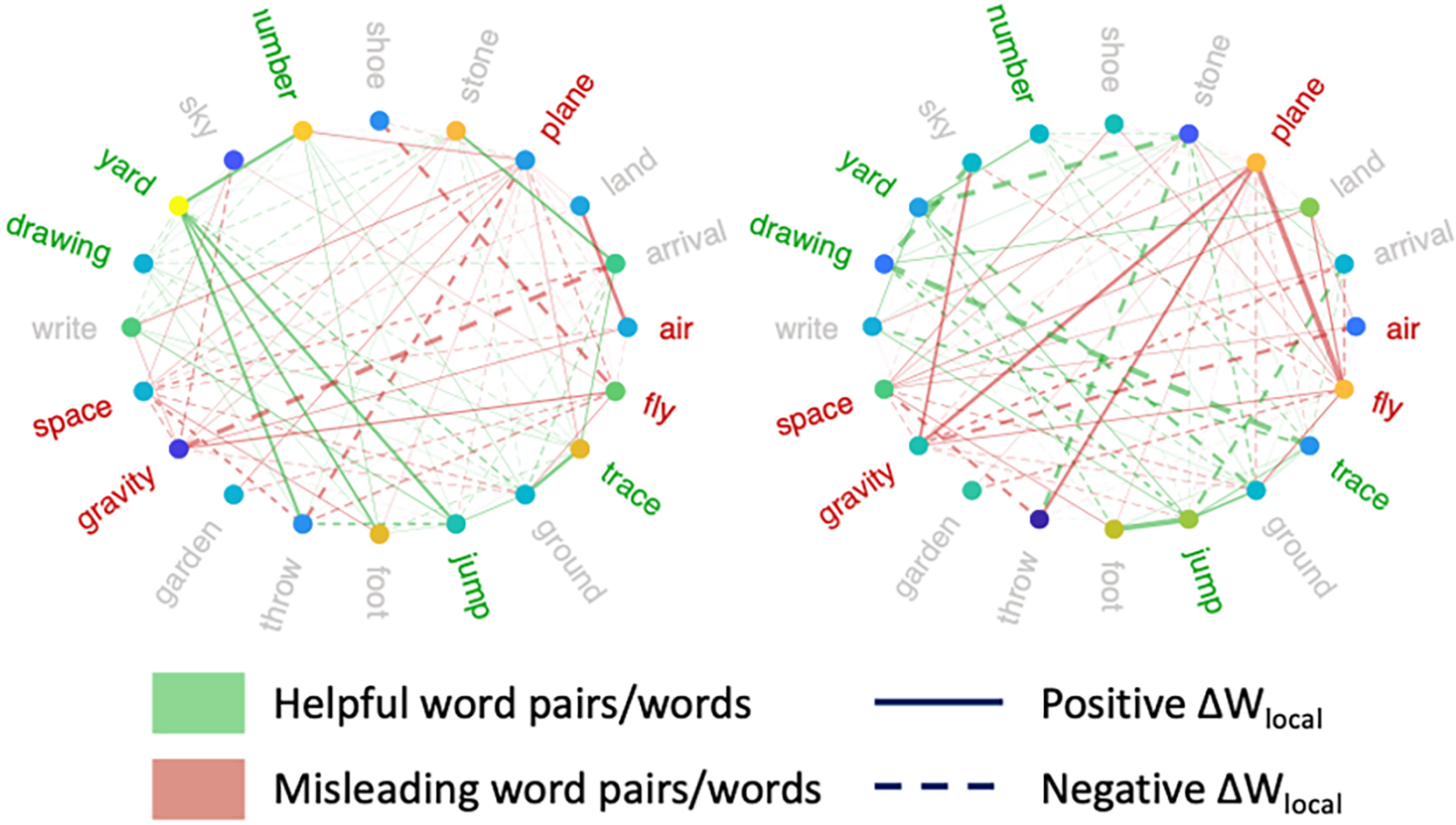


Memory restructuring

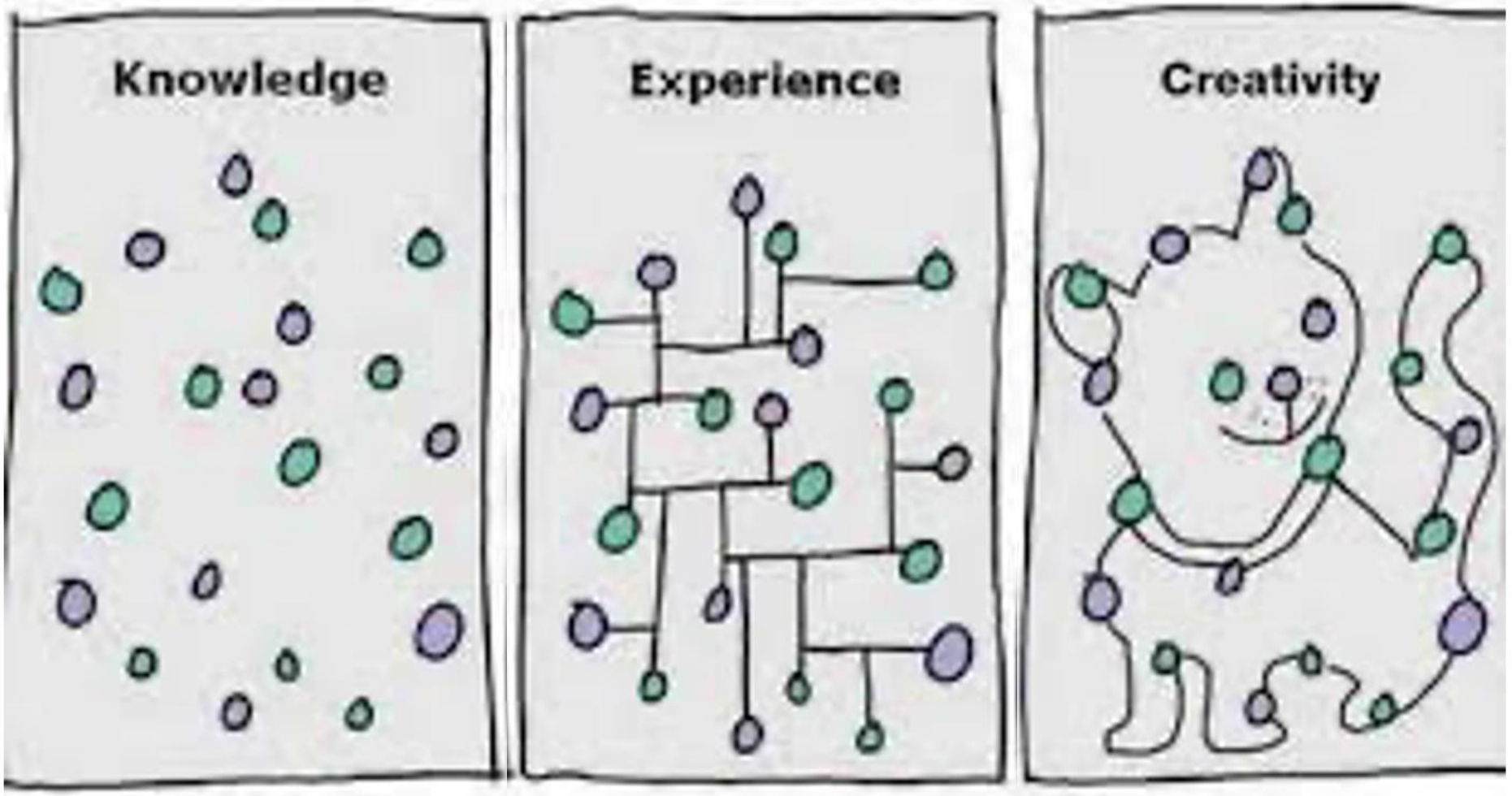
Post-SemNet – Pre-SemNet

Individual solver

Individual non-solver



Summary



Summary