When you think about the words ‘Creativity’ or ‘Creative’ what is the first thing that comes to your mind?

Identify something/someone that you consider creative. What are the main reasons for your answer?
Class Objectives

1. Introduction to the psychological study of creativity.
2. Focus on scientific research exploring creative cognition.
3. Learn about research evidence supporting techniques used to cultivate creativity.

What is creativity?
Basic Questions

Where does it come from?

Basic Questions

Are creative people ‘special’?

Basic Questions

Is there a difference between creative thinking and ordinary thinking?
The Study of Creativity

**Creativity:** A neglected research topic. Why?

1. Origins of the study of creativity in mysticism and spirituality
2. Pragmatic approaches to creativity conveyed the impression that its study is not based on psychological research.
3. Early work has employed methodologies that are not in the mainstream of psychological research.
4. Problems of definition and establishment of criteria: Creativity appears to be a trivial or elusive subject matter.
5. The belief that creativity is the result of extraordinary circumstances, hence its study is not necessary.
6. Unidisciplinary approaches to creativity that provide a narrow vision of the creative process.

Can We Study Creativity Scientifically?

**A. Creativity is a special gift:** ‘Supernatural power’ - Creative individuals (a) think differently and (b) they have different personality structures from the rest of us.

Can We Study Creativity Scientifically?

**B. Creativity is a matter of degree:** Everybody is capable of creative thinking, but: Creative people are (a) better at it and (b) have more of the ‘necessary’ personality features than the rest of us.

Teresa Amabile  Hans Eysenck  Mihaly Csikszentmihalyi
Can We Study Creativity Scientifically?

- Creativity is the product of ordinary thinking; Ordinary thinking leads to extraordinary innovations. Ordinary cognitive processes (problem solving, reasoning, memory) underlie all creative products.
- Personality factors are irrelevant.

Current Research

- Although creativity was long considered a gift of a select minority, psychologists have now revealed its seeds in mental processes such as decision-making, language and memory that all of us possess.

Basic Definitions

- Creative thinking: The type of thinking that brings about innovations
- Creative people: People who produce innovations
- Creative process: The psychological processes involved in bringing about innovations.
Basic Definitions

PROBLEM SOLVING

RANGE, CONTINUITY

ORDINARY CREATIVITY

EXTRAORDINARY CREATIVITY

Why do we care?

- Creativity has societal value
- If we understand how creativity works as a process, then we can possibly increase it or develop it.

Business

Education

Foundation View

1. Experience provides the foundation on which the creative process, produces innovations: Innovations are based on the past, but are also moving beyond it.

2. Creative discoveries come about as the result of a complex set of circumstances that psychologists can study scientifically.
The Scientific Method

- Observation
- State a hypothesis
- Manipulate variables
- Keep ‘confounding’ variables constant
- Measure behavior
- Establish the reliability of the
  - Importance of statistics
- Ability to establish cause & effect relationships

Do ideas come suddenly out of nowhere?

- **Creative product** = Completely novel?
- Are there creative products without antecedents?
- Are they created ‘ex nihilo’?
- God’s creativity vs. human creativity: Not entirely subjective, created without a context, an environment.

How about intentionality?

- Does one have to **intend** to take a particular course of action toward a goal to be considered creative?
  - Thought process in pursuit of a goal.
Creativity =

Cognitive-Emotional Process

- Creativity
- Knowledge
- Goal Pursuit
- Intention
- Personality (personal history)
- Biology

Pursuit of novelty; effortful process

*Creativity methods apply more or less for each component
*Some are purely descriptive

Context: personal, historical, social

Beyond Art: Problem Solving & Creativity in Everyday Life

- Problem solving: A situation in which a person develops and implements plans so as to move from a problem state to a goal state within a range of constraints.

Types of Problems

- Well-defined/Close-ended problems:
  - Both the goal to be achieved and the path to be followed for the solution are obvious.
  - The problem is perceived as having one correct answer.

125 × 5 = ?
Types of Problems

- **Ill-defined/Open-ended problems:**
  - Both the goal and the steps necessary for its completion are open to interpretation.
  - The solution possibilities appear infinite.

Using Objects to Solve Problems

- **Goals**
  - Continuous interaction between two processes:
    - Top-down (goal-driven)
    - Bottom-up (stimulus-driven)

Problem Solving Strategies

- ‘Special’ thinking processes—insight
  (e.g., Knoblich et al., 2001; Knoblich et al., 1999; Metcalfe, 1988b; Metcalfe & Wiebe, 1987; Ohisson, 1984, 1992)

- Ordinary cognitive processes—comprehension, memory
  (e.g., Chronicle et al., 2004; Chronicle et al., 2001; McGregor et al., 2001; Perkins, 1981; Simon, 1986; Weisberg, 1986, 1995a; Weisberg & Alba, 1981)
Our Research Question

- How does a person’s knowledge and experience define how they will go about solving a problem?

Main Argument

1) When people attempt to achieve a goal they activate knowledge that is relevant to the achievement of that goal within that context.

2) The process of establishing relationships between one’s knowledge and the information provided in the problem-solving situation involves numerous categorizations of objects or other problem elements.

(Chrisyikou, 2006; JEP:LMC, 2008)

Categorization/Conceptualization

- The active and dynamic process of constructing a (temporary) working concept within a particular context.

(Barsalou, 1987; 1993; 1999; Simmons & Barsalou, 2003)
Model for Problem Solving

- Success in goal-achievement depends on someone’s ability to categorize and re-categorize an object in an ad hoc, goal-directed manner to serve specific goals.

Recap of Part I

1. Creativity is not a gift for the selected few; rather, it is based on ordinary cognitive processes such as decision-making, language and memory that all of us possess.
2. A person’s efficiency in solving problems may depend on their ability to categorize and re-categorize the world around them within a given context.
Evidence from Neuroscience

- Is creative generation associated with a particular neural state?
- Is creative implementation associated with a different neural state?
- How does the brain allow for such dynamic flexibility within our knowledge base when one is trying to achieve a goal?

Prefrontal Cortex & Close-ended Tasks

- Important role of the frontal lobes in close-ended, higher-order cognitive tasks that require a certain level of cognitive control:
  - Working memory tasks
  - Rule switching
  - Interference resolution

Prefrontal Cortex & Open-ended Tasks

- Is the prefrontal cortex similarly implicated in open-ended tasks?
- Regional tradeoffs?
  - Anterior-posterior regions
Cognition Without Control
When a Little Frontal Lobe Goes a Long Way
Sharon L. Thompson-Schill, Michael Ramnaroop, and Evangelia G. Chrysikou
University of Pennsylvania and Stanford University

- Evolutionary tradeoffs
- Lack of prefrontal control is associated with children's lower performance in cognitive control & working memory tasks
- Difficulties in inhibition

- Heterochronous PFC development is critical for cognitive development
- Learning of linguistic, social conventions
- Hypofrontality may be important for creativity

Involvement of PFC depending on the task?

Recent Evidence from Neuroscience
Recent Evidence from Neuroscience

- Evidence from electroencephalogram studies
- Spontaneous creativity in patients with neurodegenerative diseases
- Evidence from patients with brain injuries
- Evidence from dyslexia
- Evidence from autism
- Tradeoffs between anterior & posterior regions in normal subjects

Recent Evidence from Neuroscience

- Ideational fluency has been associated with diffuse electroencephalogram (EEG) response patterns in prefrontal regions.
  (e.g., Mölle et al., 1999)

Recent Evidence from Neuroscience

- Structural and functional enhancements in non-dominant posterior neocortex may give rise to specific forms of visual creativity that can be liberated by dominant inferior frontal cortex injury (primary progressive aphasia)
  (Seeley et al., 2006)
Fig. 8 Serial MRI scans performed to follow AAs acoustic neuroma, showing emergent atrophy within the left frontal operculum. Scans performed before AAs PPA diagnosis reveal no definite cortical atrophy, which becomes evident by 2002 around the left fronto-insular region, with widening of sulci and the Sylvian fissure compared to the right hemisphere (ovals). Each MRI is paired with a representative painting from the same year.

**Recent Evidence from Neuroscience**

- Patients with left prefrontal lesions **outperform** normal subjects on open-ended components of a matchstick arithmetic task. (Ronseretti et al., 2005, Brain, 128, 2982-2990)

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<thead>
<tr>
<th>Problem Types</th>
<th>Problem</th>
<th>Solution</th>
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<tbody>
<tr>
<td>A</td>
<td>IV = II = II</td>
<td>VI = III = III</td>
</tr>
<tr>
<td>B</td>
<td>V = III = II</td>
<td>V = III = VI</td>
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<tr>
<td>C</td>
<td>VI = VI = VI</td>
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**Type A:** Move a matchstick that is part of a numeral to another numeral.

**Type B:** Move the matchstick from the equal sign to a minus sign, in order to change it into an equal sign.

**Type C:** A plus sign needs to be changed by rotating its vertical matchstick 90 degrees into an equal sign. This action transforms the equation into a tautology.

- A developmental delay in the dominant hemisphere in children with dyslexia, may lead to a disinhibition of the non-dominant hemisphere (or posterior neocortex structures) that can unmask artistic creativity in some individuals.

- Questions of laterality, hemispheric asymmetry

(Chakravarty, 2009, Medical Hypotheses, 73, 569-577)
Recent evidence from neuroscience

- The asymmetrical development of the cerebral hemispheres in autism may
delay access to low-level information. Some autistic children become artistic,
musical, or mathematical savants.

(Snyder et al., 2003, Snyder, 2009)

fMRI Study: Hypothesis

- The left ventrolateral PFC will facilitate performance in closed-ended tasks that
depend on the controlled retrieval of conceptual memory through the selection
of a prepotent response.

- Posterior temporal-occipital regions will support performance in open-ended tasks
that may benefit from a broader activation of conceptual memory.

(Chrysikou & Thompson-Schill, 2017, Human Brain Mapping; Dietrich, 2004)

Hypothesis

- **Close-ended task:** Generating the Common
  Use for everyday objects
  (e.g., **baseball bat**, to play baseball;
   **belt**, to keep one’s pants up)

- **Open-ended task:** Generating an Uncommon
  Use for everyday objects
  (e.g., **baseball bat**, to use as a rolling pin;
   **belt**, to use as a tourniquet)
Results

- **Behavioral results**: Analysis of response types
- Analysis across the entire brain:

  1. Are there specific brain regions that are more active for the **Common Use** task relative to the low-level non-conceptual task?
  2. Are there specific brain regions that are more active for the **Uncommon Use** task relative to the low-level non-conceptual task?
Summary of fMRI Experiment 1

The results reveal a tradeoff between anterior and posterior brain systems (PFC & left fusiform gyrus) in open-ended tasks.

Goal Implementation

- Experiment 1 revealed tradeoffs between PFC and posterior brain systems in a bottom-up, data-driven task.

- Experiment 2 investigated PFC functioning during goal implementation in a top-down, goal-driven task.
Experiment 2: Hypothesis

When faced with an impromptu goal, establishing a match between the task requirements and relevant, bottom up information in the environment will be associated with increased activity in PFC.

fMRI Paradigm & Tasks

A. Common object condition (n = 15)

B. Uncommon object condition (n = 15)

Common object Local Maximum

<table>
<thead>
<tr>
<th>t</th>
<th>X</th>
<th>Y</th>
<th>Z</th>
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<tbody>
<tr>
<td>9.54</td>
<td>-48</td>
<td>27</td>
<td>10</td>
</tr>
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Left inferior frontal gyrus (BA 45)

Common > Baseline

t > 7.05, p < .05 (permuted)
Conclusion

- Evidence for increased left PFC activation when participants implement a goal under unexpected circumstances.

(Chrysikou & Thormpso-Scholl, in preparation)
rapid transcranial magnetic Stimulation (rTMS)

- Can we induce these effects in normal subjects?
- rTMS: A noninvasive technique used to alter the excitation of neurons by rapidly changing their magnetic fields and which is achieved by inducing weak electric currents in brain tissue.

recent evidence from neuroscience

- rTMS over the left fronto-temporal lobe induced savant-like effects in normal subjects
  - Improved numerosity skills (absolute number estimation)

Figure 3. Mean ability across all participants to make guesses within the bull-eye criterion of 5. Error bars represent 95% confidence intervals.
Transcranial Direct Current Stimulation (tDCS)

- Can we facilitate object re-categorization by inhibiting the left PFC?

Transcranial Direct Current Stimulation (tDCS)

- A noninvasive technique that involves the application of small currents (typically 1-2 mA) to the scalp for a few minutes through two surface electrodes, which can modulate cortical excitability.

Design & Methods

- 48 participants
- Common & Uncommon Use tasks
  - 60 grayscale images of everyday objects
  - Forward Digit Span (FDS) Control Task
- Participants randomly assigned in 1 of 6 conditions

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<thead>
<tr>
<th> </th>
<th>Common Use Task</th>
<th>Uncommon Use Task</th>
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<tr>
<td>Left (F7) cathodal stimulation (1,200 seconds)</td>
<td>n = 8</td>
<td>n = 8</td>
</tr>
<tr>
<td>Right (F8) cathodal stimulation (1,200 seconds)</td>
<td>n = 8</td>
<td>n = 8</td>
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<tr>
<td>Sham (over F7 or F8) direct current stimulation (60 seconds)</td>
<td>n = 8</td>
<td>n = 8</td>
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Results

Number of No Responses

Qualitative Analysis of Uncommon Responses
Summary of tDCS Experiment

- Facilitative effects of left PFC stimulation for the uncommon, but not the common, use generation task.
- There were no effects of stimulation on the control task.
- Certain tasks may benefit from tradeoff between PFC and other brain regions.

(Chrysikou et al., 2013, Cognitive Neuroscience)

Behavioral Techniques

- Training participants in re-categorizing objects can improve their performance on open-ended tasks.

(Chrysikou, 2006, JEP:LMC)

Method

Participants: N = 140 (45 males; mean age = 19.06 years)

Conditions by Type of Training Task:
(i) Alternative Categories Task with critical items (ACT-C, n = 35)
(ii) Alternative Categories Task (ACT, n = 35)
(iii) Embedded Figures Test-Control Task (EFT, n = 35)
(iv) Baseline (Baseline, n = 35)
Problem Solving Measures

Open-ended Problems
1. The Charlie problem
2. The Candle problem
3. The Pyramid & Dollar Bill problem
4. The Fake Coin problem
5. The Two-String problem
6. The Prisoner problem
7. The Ten-Coin problem

- All problems involve everyday objects
- 2/3 of participants followed verbalization procedure
- The time allocated for each problem was 8 minutes
- Participants were explicitly told of the relevance of the training for problem solving

Results

Summary of Experiment 1

1. The alternative categorization tasks (ACT-C & ACT) significantly enhanced participants’ performance.
2. This effect was not item-specific.
3. The effects cannot be attributed to a general training to “think flexibly,” but to a specialized training in goal-derived object re-categorization.
Experiment 2

- Will the training effects still be observed when participants do not receive explicit instructions regarding the relevance of the training task for problem-solving?

Method

Participants: N = 80 (18 males; mean age = 20.53 years; 20 per condition)

- Method identical to Experiment 1, without explicit instructions regarding the relevance of the training for problem-solving.

Results

- Baseline
- Alternative Categories with Critical Items Training (ACT-C)
- Alternative Categories Training (ACT)
- Embedded Figures Training (EFT)
Summary of Experiment 2

1. Replication of the results of Experiment 1.

2. The effects of the training can be obtained implicitly (without instructions regarding the relevance of the training to problem solving).

Educational Applications

Broader Implications

- View of the prefrontal cortex as a dynamic filtering mechanism that selectively maintains task-relevant information while gating task-irrelevant information.

(e.g., Brauer & Hannes, 2006; Dosenbach et al., 2008; Frith, 2000; Rowe et al., 2007; Shimamura, 2000)
Conclusions

1. Creativity depends on ordinary cognitive processes that all of us possess.
2. Creativity may depend on tradeoffs between anterior and posterior brain regions depending on the task.
3. Creativity can be trained; this has direct applications for education and clinical practice.

thank you!