BVSR ≠ **Buffy Vampire Slayer Relationships**

Creative Problem Solving as Campbellian BVSR

Quantitative Creativity Measure
and Blind-Sighted Metric

Background

- Donald T. Campbell’s (1960) BVSR model of creativity and discovery
- Then controversies and confusions
- e.g., randomness, equiprobability, volition, Darwinism … ad infinitum
- total chaos for the next 50 years!
- Then it dawned on me:

Background

- Nobody – neither proponents nor opponents – knew what they were talking about!
- Absolutely nobody defined their terms!
- Not even Campbell!

Background

- Hence, we need a formal treatment that allows logical deductions and demonstrations
- To keep the discussion simple, this treatment will be expressed in terms of creative problem solving

Definitions

- Given a problem that needs to be solved:
  - Goal with attainment (utility) criteria
  - For complex problems: subgoals with their separate attainment criteria
  - Goals and subgoals may form a goal hierarchy
    - e.g., writing a poem: the composition’s topic or argument, its length and structure, meter or rhythm, rhyme and alliteration, metaphors and similes, and the best word for a single place that optimizes both sound and sense (cf. Edgar Allan Poe’s 1846 “The Philosophy of Composition”)

Definitions

- *Solution variants* (alternative solutions or parts of solutions): e.g.,
  - algorithms, analogies, arrangements, assumptions, axioms, colors, conjectures, corollaries, definitions, designs, equations, estimates, explanations, expressions, forms, formulas, harmonies, heuristics, hypotheses, images, interpretations, media, melodies, metaphors, methods, models, narratives, observations, parameters, patterns, phrasings, plans, predictions, representations, rhymes, rhythms, sketches, specifications, start values, statistics, structures, techniques, terms, themes, theorems, theories, words …
  - all depending on nature of problem

Definitions

- Creative solution:
  - Three-criterion definitions
    - US Patent Office: new, useful, and nonobvious
    - Boden (2004): novel, valuable, and surprising
    - Amabile (1996):
      - novel
      - appropriate, useful, correct, or valuable
      - heuristic rather than algorithmic

Definitions

- Creative solution:
  - To wit, creativity requires some degree of a “Eureka!” or “Aha!” experience
  - Cf. “reasonable” versus “unreasonable” problems (Perkins, 2000):
    - *reasonable* problems “can be reasoned out step by step to home in on the solutions.”
    - *unreasonable* problems “do not lend themselves to step-by-step thinking. One has to sneak up on them.”

Definitions

- Creative solution: Here -
  - original (rather than "novel")
  - useful (noun "utility")
  - surprising (noun "surprisingness")
    - innovations, not mere adaptations
    - inventions, not just improvements
    - productive, not reproductive thought

Definitions

- Solution parameters: x_i characterized by
  - *initial* generation probability: p_i
    - hence, solution variant *originality* = $(1 – p_i)$
  - *final* utility: u_i (probability or proportion): either
    - probability of selection-retention, or
    - proportion of *m* criteria actually satisfied
  - prior information: v_i (actual knowledge of u_i)
    - hence, solution variant *surprisingness* = $(1 – v_i)$
- N.B.: These parameters are *subjective*

k Solution Variants

Solution	Probability	Utility	Information
x_1	p_1	u_1	v_1
x_2	p_2	u_2	v_2
x_3	p_3	u_3	v_3
…	…	…	…
x_i	p_i	u_i	v_i
…	…	…	…
x_k	p_k	u_k	v_k

$$0 < p_i \leq 1, \Sigma\, p_i \leq 1;$$

$$0 \leq u_i \leq 1, \Sigma\, u_i \leq k; 0 \leq v_i \leq 1, \Sigma\, v_i \leq k$$

Two Special Types

- **Reproductive:**
  - $p_i = u_i = v_i = 1$
  - i.e., low originality, high utility, low surprise
  - BVSR utterly unnecessary because variant "frontloaded" by *known* utility value
  - i.e., u_i implies p_i via v_i
  - Selection reduces to mere "quality control" to avoid calculation mistakes or memory slips
  - But also routine, even algorithmic thinking, and hence not creative

Two Special Types

- **Productive:**
  - $p_i \neq 0$ but $p_i \approx 0$ (high originality)
  - $u_i = 1$ (high utility)
  - $v_i = 0$ or $v_i \approx 0$ (high surprise)
  - BVSR mandatory to distinguish productive from potential solutions where $p_i \neq 0$ and $v_i = 0$ but $u_i = 0$
  - i.e., because the creator *does not know* the utility value, must generate and test to find out
  - Hence, innovative, inventive, or creative thinking

Obtaining Quantitative Indices

- The creativity of single solution variants
- The “sightedness” of solution sets

Creativity Measure

- What is the most creative solution in the set of k solutions?
- $c_i = (1 - p_i)u_i(1 - v_i)$
- where $0 \leq c_i < 1$ (N.B.: why $c_i \neq 1$)
- $c_i \longrightarrow 1$ as
  - $p_i \longrightarrow 0$ (maximizing originality),
  - $u_i \longrightarrow 1$ (maximizing utility), and
  - $v_i \longrightarrow 0$ (maximizing surprise)
- $c_i = 0$ if $p_i = 1$ and $v_i = 1$ (or $u_i = 0$)
- e.g., reproductive variant $p_i = u_i = v_i = 1$

Creativity Measure

- Examples:
  - $p_i = .1$, $u_i = 1$, $v_i = 0$, $c_i = .9$
    - fully "blind" solution
  - $p_i = .1$, $u_i = 1$, $v_i = .1$, $c_i = .81$
    - "hunch" implies less creativity
  - $p_i = .1$, $u_i = .5$, $v_i = .1$, $c_i = .405$
    - less utility implies less creativity

Creativity Measure

- Individualistic vs. collectivistic cultures:
  - letting $v_1 = v_2 = 0$
  - $p_1 = .001$ and $u_1 = .5$ (originality > utility)
  - $p_2 = .5$ and $u_2 = 1$ (originality < utility)
  - $c_1 \approx .5$ (or .4995, exactly)
  - $c_2 = .5$
  - e.g., …

Xu Daoning’s *Fishermen's Evening Song*

Jackson Pollock’s *No. 5, 1948*

Blind-Sighted Metric

- Goal: a measure for any set of *k* solution variants that indicates the relative amount of sightedness and blindness:
  - $S = 1/k \sum p_i u_i v_i$, where $0 \leq S \leq 1$
  - $S = 1$ when set is perfectly "sighted"
  - $S = 0$ when set is perfectly "blind"
  - Why v_i must be included in the metric (viz. necessary and sufficient metric that forbids "lucky guesses")
- Hence, blindness $B = 1 – S$
- Combining with the creativity measure …

"Fork in the Road" $k = 2$

Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2

“Fork in the Road” $k = 2$

Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2
1	1	0	1	0	1	0	1	0	[0]

“Fork in the Road” $k = 2$

Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2
1	1	0	1	0	1	0	1	0	[0]
2	.5	.5	1	0	0	0	0	.5	0

"Fork in the Road" $k = 2$

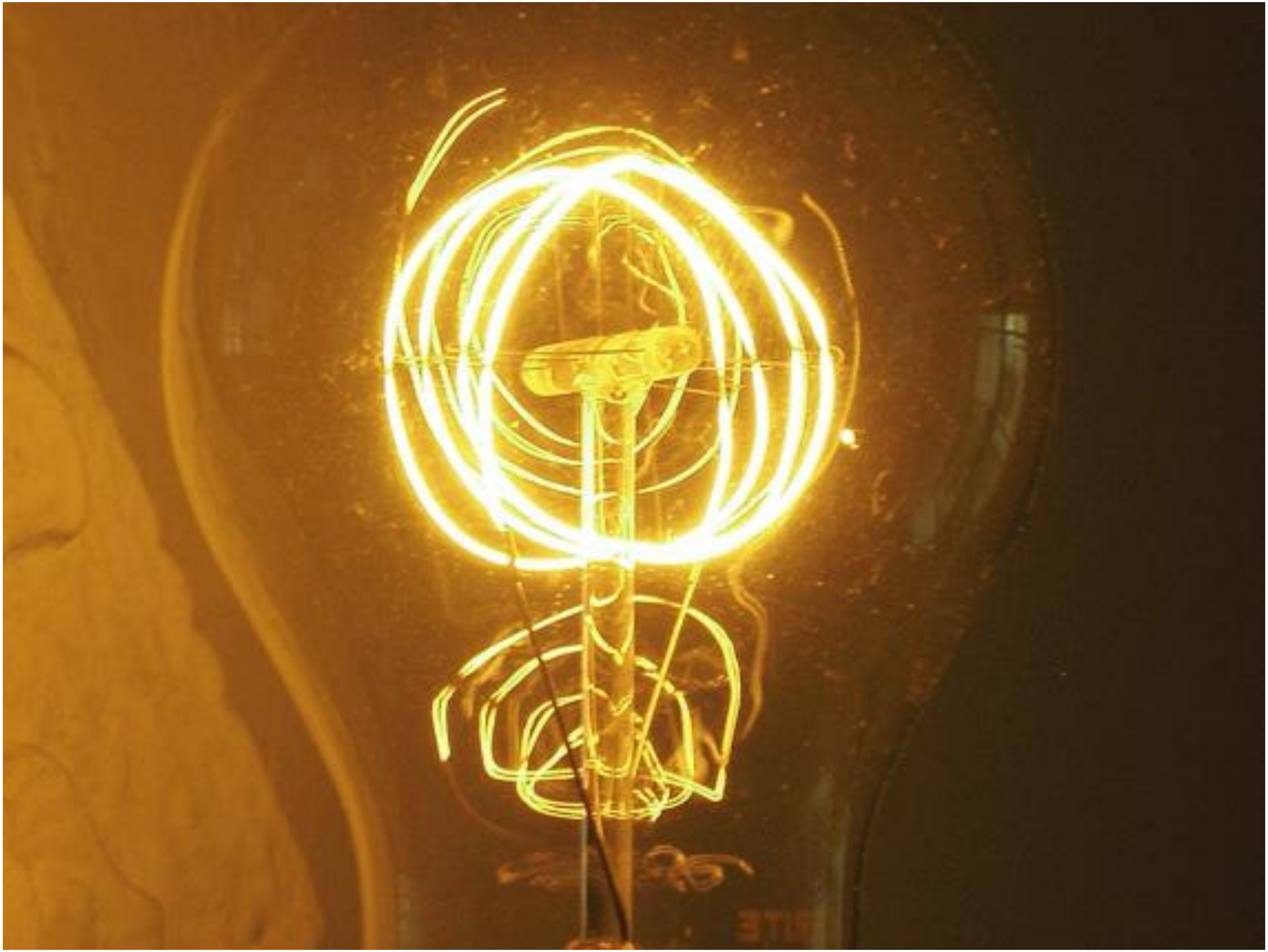
Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2
1	1	0	1	0	1	0	1	0	[0]
2	.5	.5	1	0	0	0	0	.5	0
3	.6	.4	1	0	.1	0	.06	.36	0

“Fork in the Road” $k = 2$

Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2
1	1	0	1	0	1	0	1	0	[0]
2	.5	.5	1	0	0	0	0	.5	0
3	.6	.4	1	0	.1	0	.06	.36	0
4	0	1	1	0	0	0	0	[0]	0

“Fork in the Road” $k = 2$

Case	p_1	p_2	u_1	u_2	v_1	v_2	S	c_1	c_2
1	1	0	1	0	1	0	1	0	[0]
2	.5	.5	1	0	0	0	0	.5	0
3	.6	.4	1	0	.1	0	.06	.36	0
4	0	1	1	0	0	0	0	[0]	0
5	1	0	0	0	0	0	0	0	[0]



Edison's "drag hunt" to find an incandescent filament that …

- has low-cost,
- features high-resistance,
- glows brightly 13½ hours, and
- is durable

Solution Equiprobability: Total Ignorance: Exploration

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$

Solution Equiprobability: Total Ignorance: Exploration

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	0	0	.5	0

Solution Equiprobability: Total Ignorance: Exploration

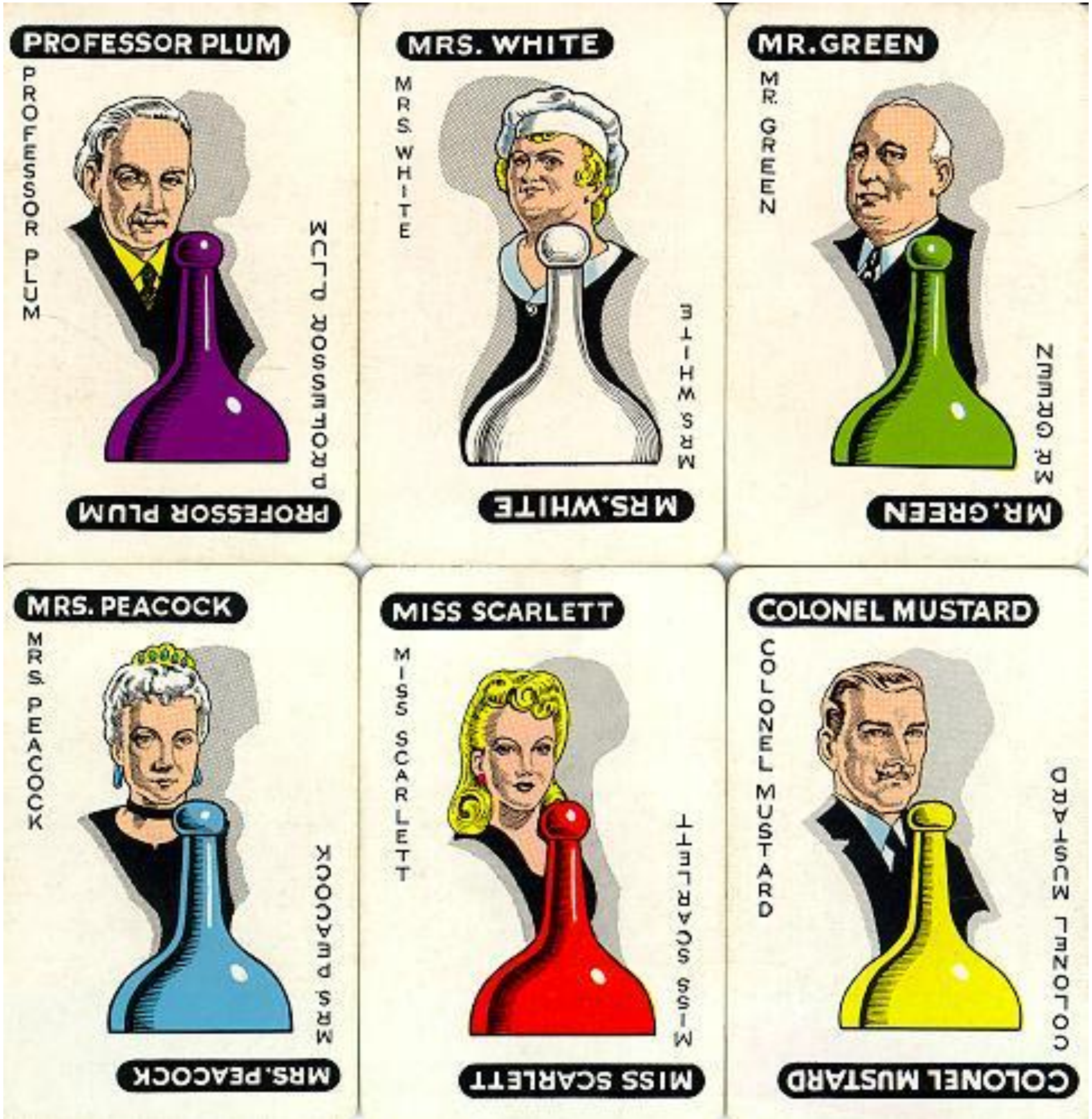
k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	0	0	.5	0
3	.33	1	0	0	0	.67	0

Solution Equiprobability: Total Ignorance: Exploration

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	0	0	.5	0
3	.33	1	0	0	0	.67	0
4	.25	1	0	0	0	.75	0

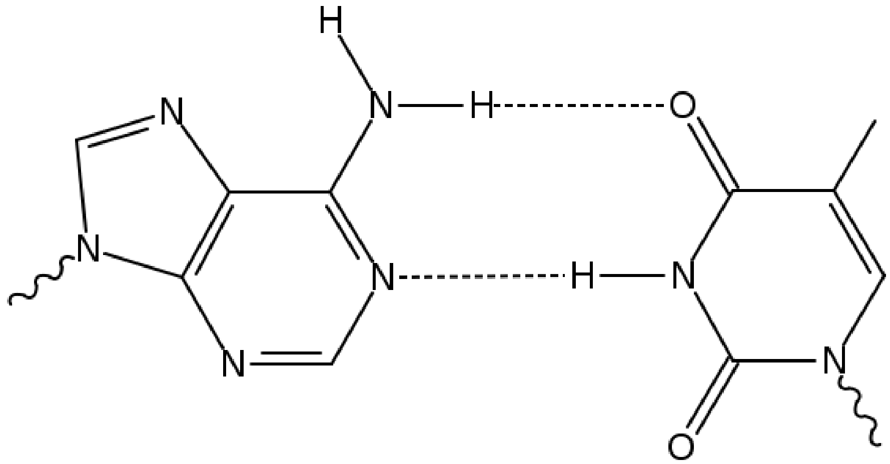
Solution Equiprobability: Total Ignorance: Exploration

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	0	0	.5	0
3	.33	1	0	0	0	.67	0
4	.25	1	0	0	0	.75	0
5	.20	1	0	0	0	.80	0

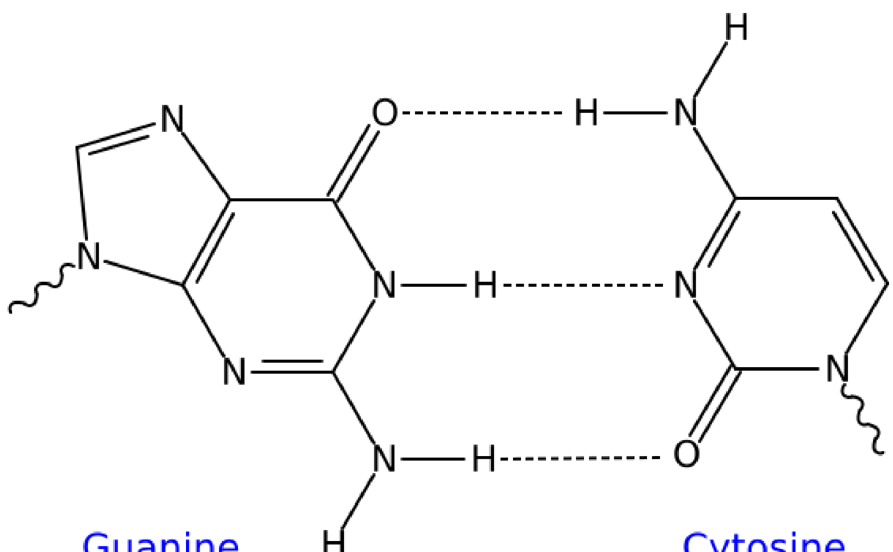

PROFESSOR PLUM
MRS. WHITE
MR. GREEN
MRS. PEACOCK
MISS SCARLETT
COLONEL MUSTARD

Watson's Discovery of the DNA Base Pairs

- Four bases (nucleotides):
  - two purines: adenine (A) and guanine (G)
  - two pyrimidines: cytocine (C) and thymine (T)
- Four solution variants:
  - x_1 = A-A, G-G, C-C, and T-T
  - x_2 = A-C and G-T
  - x_3 = A-G and C-T
  - x_4 = A-T and G-C



Adenine Thymine



Guanine Cytosine

Solution Equiprobability: Informed Guess: Elimination

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$

Solution Equiprobability: Informed Guess: Elimination

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	.5	.25	.25	0

Solution Equiprobability: Informed Guess: Elimination

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	.5	.25	.25	0
3	.33	1	0	.33	.11	.45	0

Solution Equiprobability: Informed Guess: Elimination

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	.5	.25	.25	0
3	.33	1	0	.33	.11	.45	0
4	.25	1	0	.25	.06	.56	0

Solution Equiprobability: Informed Guess: Elimination

k	p_i	u_1	u_i $i \neq 1$	v_i	S	c_1	c_i $i \neq 1$
2	.5	1	0	.5	.25	.25	0
3	.33	1	0	.33	.11	.45	0
4	.25	1	0	.25	.06	.56	0
5	.20	1	0	.20	.04	.64	0

Hence, variant superfluity → BVSR

Selection Procedures

- External versus Internal
  - Introduces no complications
- Simultaneous versus Sequential
  - Latter introduces complications
  - In particular, although sightedness will tend to increase with successive generate-and-tests, this upward tendency need not be monotonic or incremental when no solution has perfect utility
  - The consequence: Backtracking → BVSR

Selection Procedures

- Two alternative sequential scenarios
  - Informed guess: Elimination
  - Total ignorance: Exploration
- In both scenarios assume that *u*-max = .9
  - i.e., no perfect solution, but one that is satisfactory

Selection Procedures

- Consequences for p_i:
  - When a solution is tested and rejected its probability (temporarily) set to zero
  - For the remaining solutions, two scenarios
    - Elimination: normalization $\Sigma\, p_i = 1$ at each trial because BVSR ensures solution identification
    - Exploration: no normalization, so that remaining probabilities remain unchanged
      - because BVSR does not ensure solution identification
      - the solution set may contain no solution, partial or otherwise

First:
Sequential Selection

Informed guess: Elimination

Sequential Selection: Informed guess: Elimination

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	.1	.007

c-max c_2 = .57 [= (1 - .3)(.9)(1 - .1)]

B_1 = .993

Sequential Selection: Informed guess: Elimination

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	.1	.007
2	3	0	0	.5	.9	.33	.3	.17	.4	.1	.012

c-max c_2 = .57 **N.B.: $\Sigma\, p_i$ = 1 (normalization)** B_2 = .988

Sequential Selection: Informed guess: Elimination

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	.1	.007
2	3	0	0	.5	.9	.33	.3	.17	.4	.1	.012
3	2	0	0	0	.9	.67	.3	.33	.4	.1	.008

c-max $c_2 = .57$

$B_3 = .992$

Sequential Selection: Informed guess: Elimination

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	.1	.007
2	3	0	0	.5	.9	.33	.3	.17	.4	.1	.012
3	2	0	0	0	.9	.67	.3	.33	.4	.1	.008
4	1	0	0	0	.9	0	.3	1	.4	.1	.04

c-max $c_2 = .57$

$B_4 = .96$

Sequential Selection: Informed guess: Elimination

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	.1	.007
2	3	0	0	.5	.9	.33	.3	.17	.4	.1	.012
3	2	0	0	0	.9	.67	.3	.33	.4	.1	.008
4	1	0	0	0	.9	0	.3	1	.4	.1	.04
5	1	0	0	1	.9	0	.3	0	.4	1	.9

c-max $c_2 = .57$

Backtrack

$B_5 = .1$

Second: Sequential Selection

Total ignorance: Exploration

Sequential Selection: Total ignorance: Exploration

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	0	0

c-max c_2 = .63 [= (1 - .3)(.9)(1 - 0)] > .57

B_1 = 1.0

Sequential Selection: Total ignorance: Exploration

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	0	0
2	3	0	0	.3	.9	.2	.3	.1	.4	0	0

c-max c_2 = .63 **N.B.: no normalization** B_2 = 1.0

Sequential Selection: Total ignorance: Exploration

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	0	0
2	3	0	0	.5	.9	.2	.3	.1	.4	0	0
3	2	0	0	0	.9	.2	.3	.1	.4	0	0

c-max $c_2 = .63$ **Temporary rejection** $B_3 = 1.0$

Sequential Selection: Total ignorance: Exploration

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	0	0
2	3	0	0	.5	.9	.2	.3	.1	.4	0	0
3	2	0	0	0	.9	.2	.3	.1	.4	0	0
4	1	0	0	0	.9	0	.3	.1	.4	0	0

c-max c_2 = .63

$B_4 = 1.0$

Sequential Selection: Total ignorance: Exploration

t	k	p_1	u_1	p_2	u_2	p_3	u_3	p_4	u_4	v_t	S_t
1	4	.4	0	.3	.9	.2	.3	.1	.4	0	0
2	3	0	0	.5	.9	.33	.3	.17	.4	0	0
3	2	0	0	0	.9	.67	.3	.33	.4	0	0
4	1	0	0	0	.9	0	.3	1	.4	0	0
5	1	0	0	1	.9	0	.3	0	.4	1	.9

c-max $c_2 = .63$

Backtrack

$B_5 = .1$

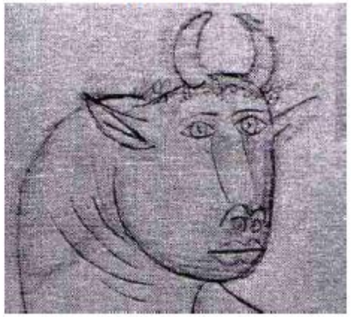
Two critical lessons

First critical lesson - Backtracking implies BVSR: e.g. …

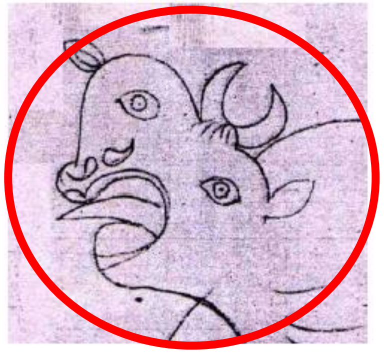
Picasso’s *Guernica* sketches

Sketch 6

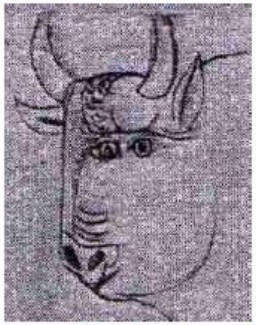
Sketch 10



Sketch 11



Sketch 12



Sketch 15

Sketch 19

Sketch 22

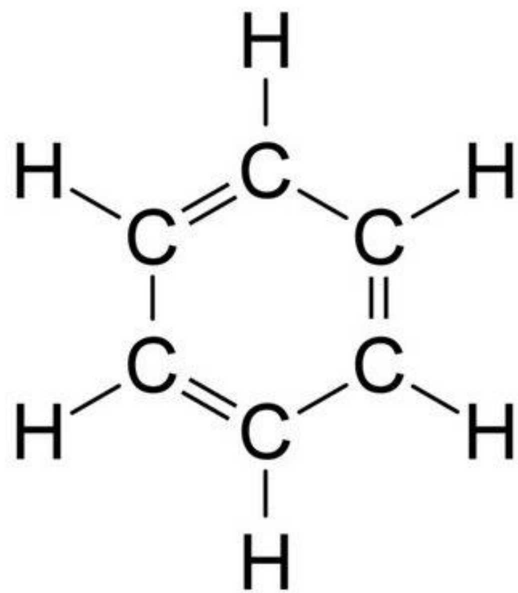
Sketch 26

Sketch 27

Final Version

Second critical lesson - BVSR increases S_t (decreases B_t): e.g. …

ouroboros



benzene ring

Discussion

- I have just shown how BVSR has an intimate connection with creative problem solving
- Moreover, I have provided the rationale for two universal BVSR signs: variant superfluity and backtracking
- However, it should be equally clear from the formal definitions that the BVSR-creativity connection is essential rather than accidental (i.e., it is not contingent on the particular computational examples shown)

Discussion

- E.g., in a set of k variants with one useful solution x_1:
  - $S \rightarrow 1$ as $p_1 \rightarrow 1$, $u_1 \rightarrow 1$, and $v_1 \rightarrow 1$,
  - and for all $i \neq 1$, $p_i \rightarrow 0$, $u_i \rightarrow 0$, and $v_i \rightarrow 0$, implying that $k \rightarrow 1$ (because $\Sigma\, p_i \leq 1$), whereas
  - $c_1 \rightarrow 1$ as $p_1 \rightarrow 0$, $u_1 \rightarrow 1$, and $v_1 \rightarrow 0$,
  - implying that $k >> 1$ (variant superfluity)
- In general, highly sighted sets cannot possibly contain highly creative solutions

Discussion

- In contrast, absolutely nothing prevents a highly creative solution from emerging in a set where $S = 0$ (i.e., $B = 1$), for
- $S = 0$ when $p_i u_i v_i = 0$ for all i, indicating that any solution with $p_i > 0$ and $u_i > 0$ must have $v_i = 0$, a stipulation consistent with $c_i >> 0$
- If $v_i = 0$, then $c_i \rightarrow 1$ as $p_i \rightarrow 0$ and $u_i \rightarrow 1$ while $S = 0$
- E.g., serendipitous discoveries

Discussion

- Yet is BVSR-creativity link so close that it lacks empirical content?
- Is it tantamount to an assertion like “All bachelors are unmarried”?
- The answer is complex:
  - On the one hand, the BVSR-creativity connection cannot be disproved empirically
  - On the other hand, the operation of BVSR in creativity can be empirically investigated!

Discussion

- For example, we can ask:
  - What cognitive processes and behavioral procedures generate sets that contain at least one solution where $p_i \to 0$, $u_i \to 1$, and $v_i \to 0$?
  - What characteristics enable a person to engage in the foregoing cognitive processes and behavioral procedures?
  - What environmental factors encourage or discourage a person from engaging in those processes or procedures?

Discussion

- To illustrate, what is the function of
  - reduced latent inhibition?
  - remote association?
  - divergent thinking?
  - behavioral tinkering?
  - general intelligence?
  - introversion?
  - “positive” schizotypy or psychoticism?
  - domain-specific expertise?
  - multicultural experiences?
- These are all valid empirical questions!

Conclusion

- What we can't deny is that BVSR $\rightarrow$ creativity
- So …
- **Donald Campbell (1960) was right!**
- [P.S.: If only he had worked out the analytical details!]