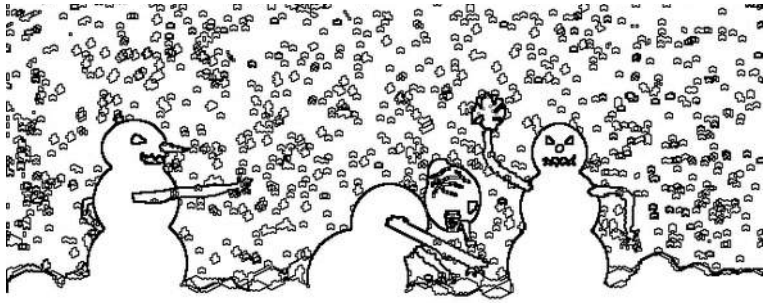
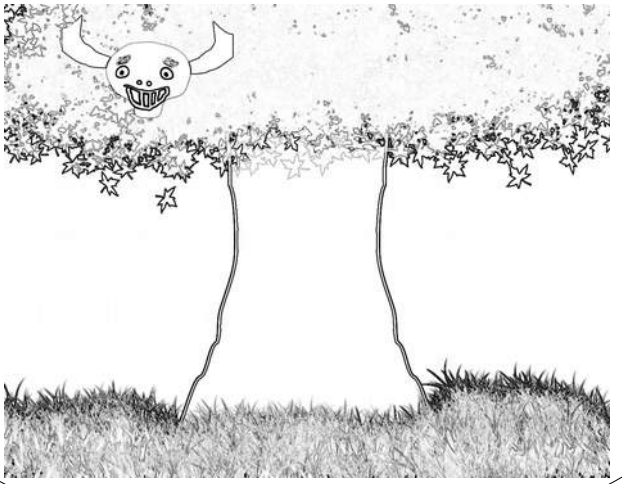
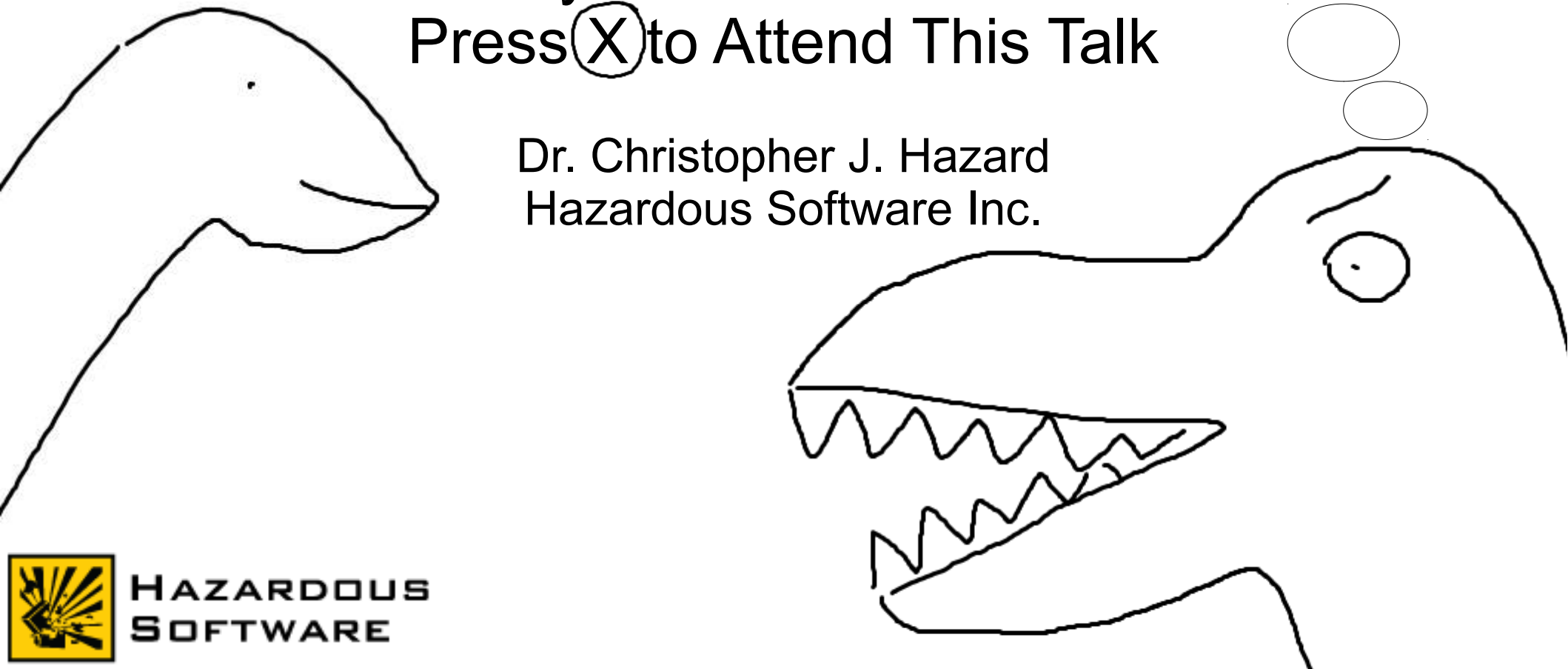




Creativity and Game Mechanics: Press X to Attend This Talk

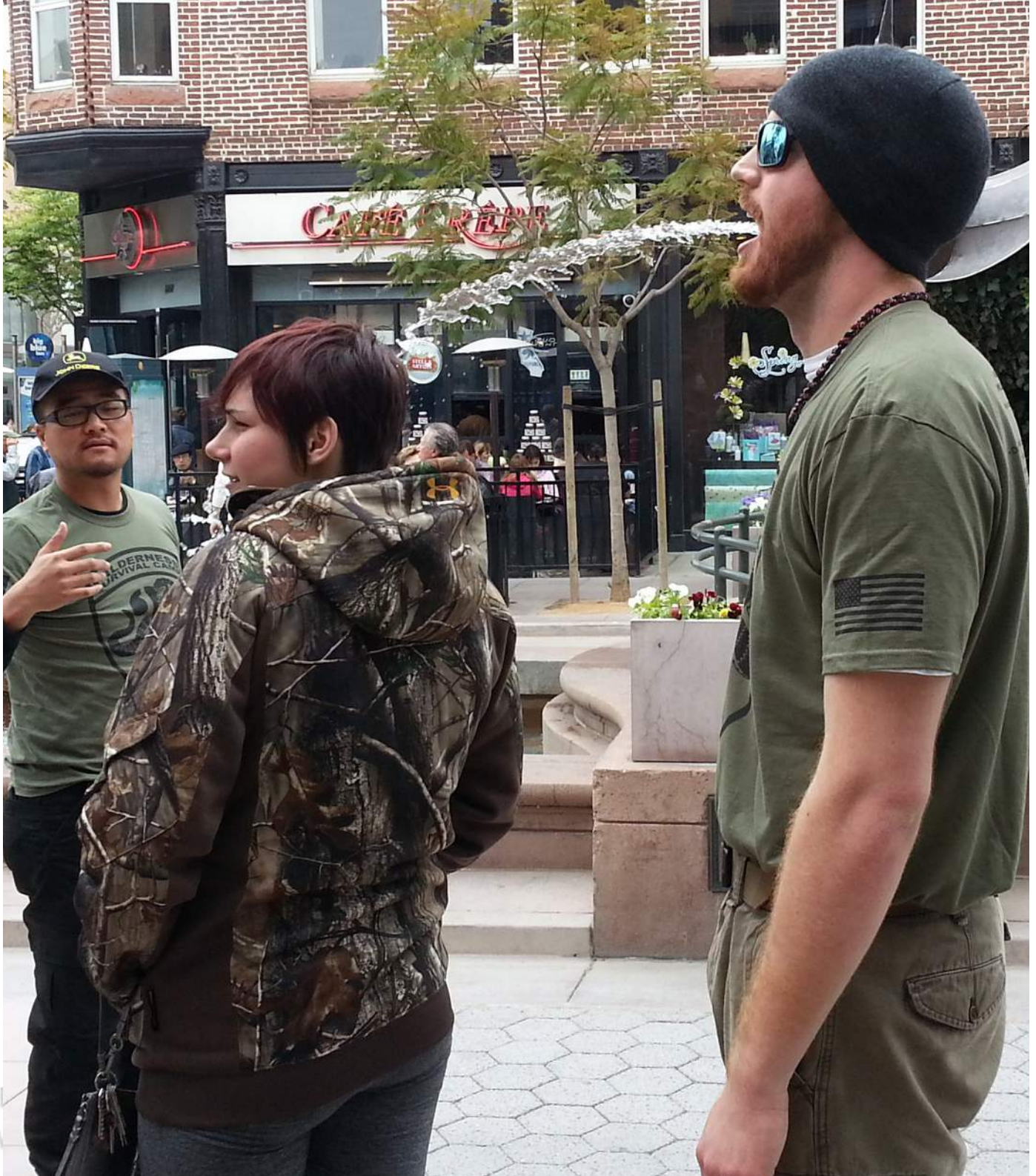
Dr. Christopher J. Hazard
Hazardous Software Inc.



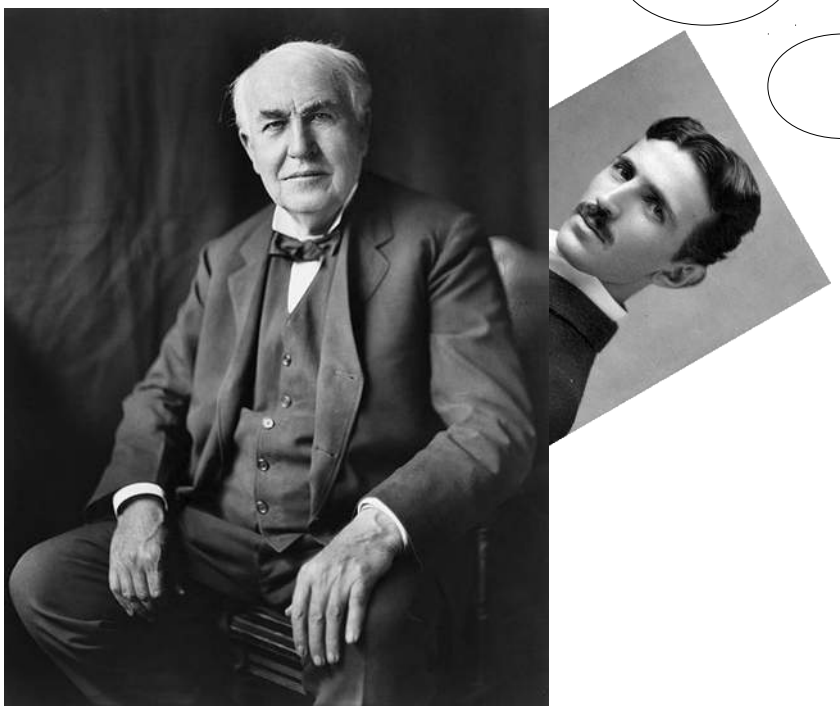
HAZARDOUS SOFTWARE

To make new and valuable things and ideas

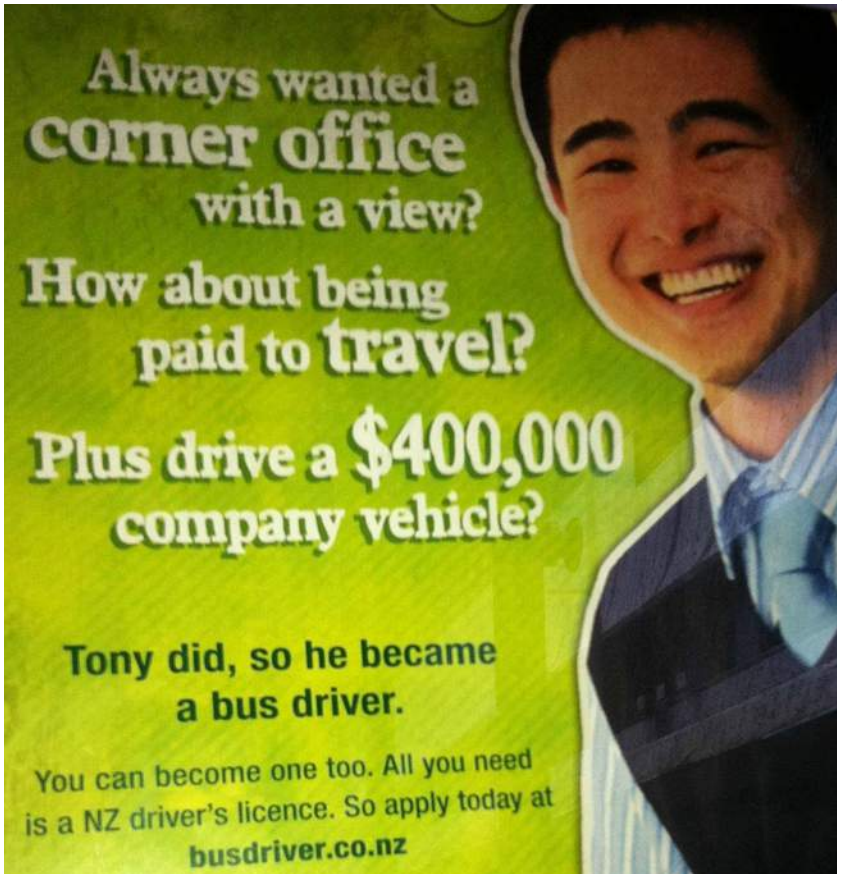
Axe Cop

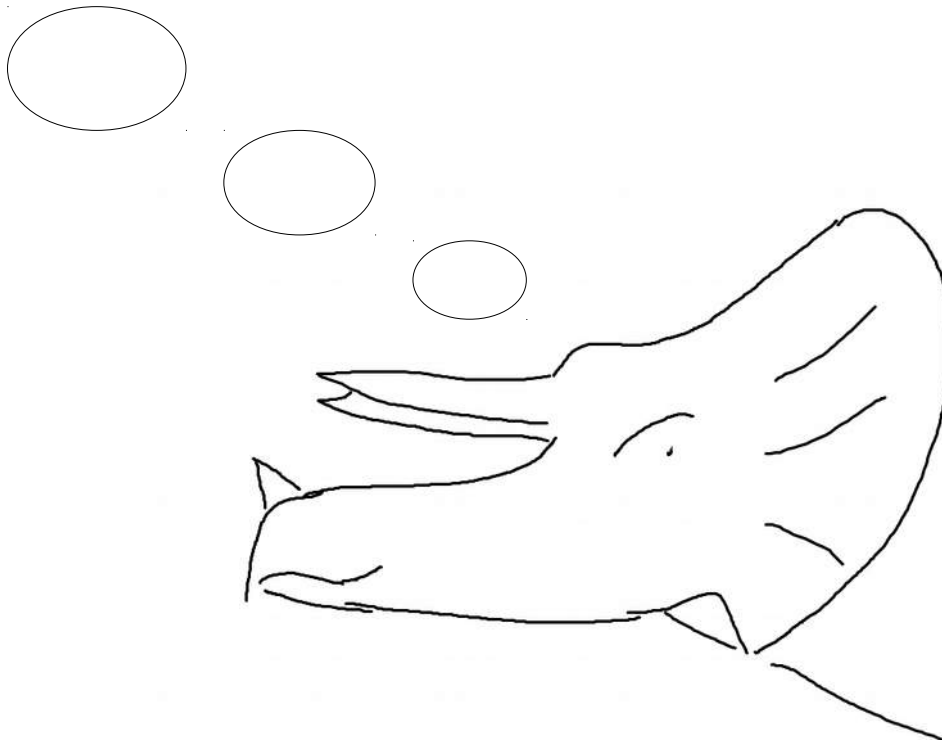

CAFE CREPE

Big "C" Creativity



Little "c" Creativity





Measuring A Person's Creativity

- Remote Associates:
  - Shoulder, Sore, Sweat
- Unusual uses, e.g., brick
- Insight problems (brain teasers)
- Self-assessment
- Name items that contain a component

Doing and Recognizing Creativity

- Recipe: relaxed brain state, extensive knowledge, divergent thinking (Heilman et al., Neurocase, 2003)
- Constraints
- Ah-ha! Moment
  - Appearences: "no self-respecting architect leaves the scaffolding in place after completing the building" - Carl Friedrich Gauss

The Fight for Creativity

- 3-fold contribution to success variance when compared to IQ (Plucker, Creativity Research J., 1999)
- Creativity falling since 1990's (K. Kim, Creativity Research J., 2011)
- Bias against creativity when faced with uncertainty (Mueller et al., Psych. Sci., 2011)
- Creatives take on risks, are non-conformists, and fight against traditional power structures (Staw; Ford & Gioia Eds, chap 37, Creative Action in Organizations, 1995)
- Most are "uncreativie", creativity is domain specific (Silvia et al., Psych of Aesth., Creat., and Arts, 2009)

Strategic Breadth (Experience, Knowledge)

Aesthetic Control (Form)

Strategic Depth (Intelligence, Search)

Scribblenauts Unlimited

LittleBIG Planet 2

Minecraft

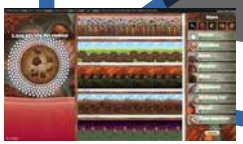
Grand Theft Auto V

Second Life

EVE Online

Kerbal Space Program

Achron



Mutual Exclusion Between Mechanical and Social Reasoning

(Jack et al., Neuroimage, 2012)

Strategic Breadth (Experience, Knowledge)

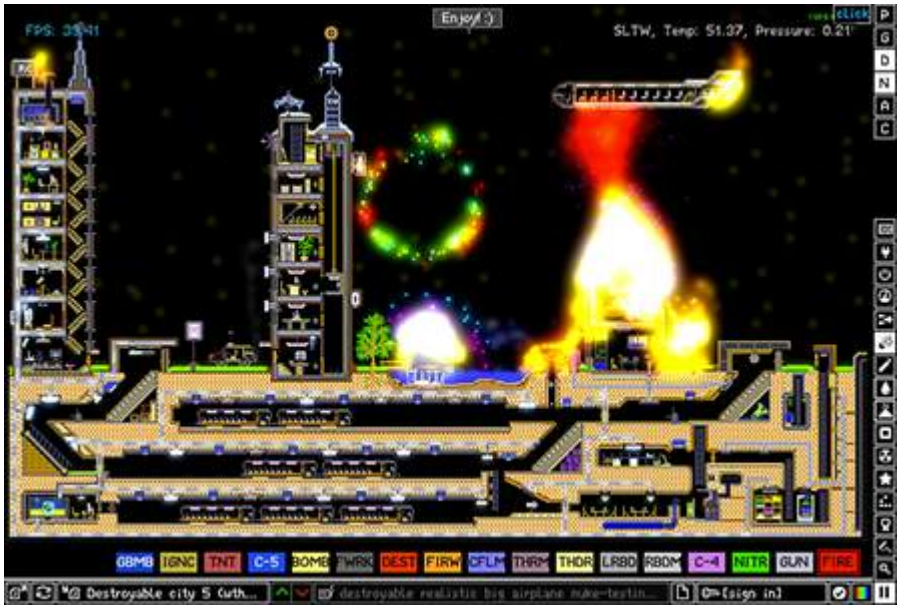
Aesthetic Control (Form)

Strategic Depth (Intelligence, Search)

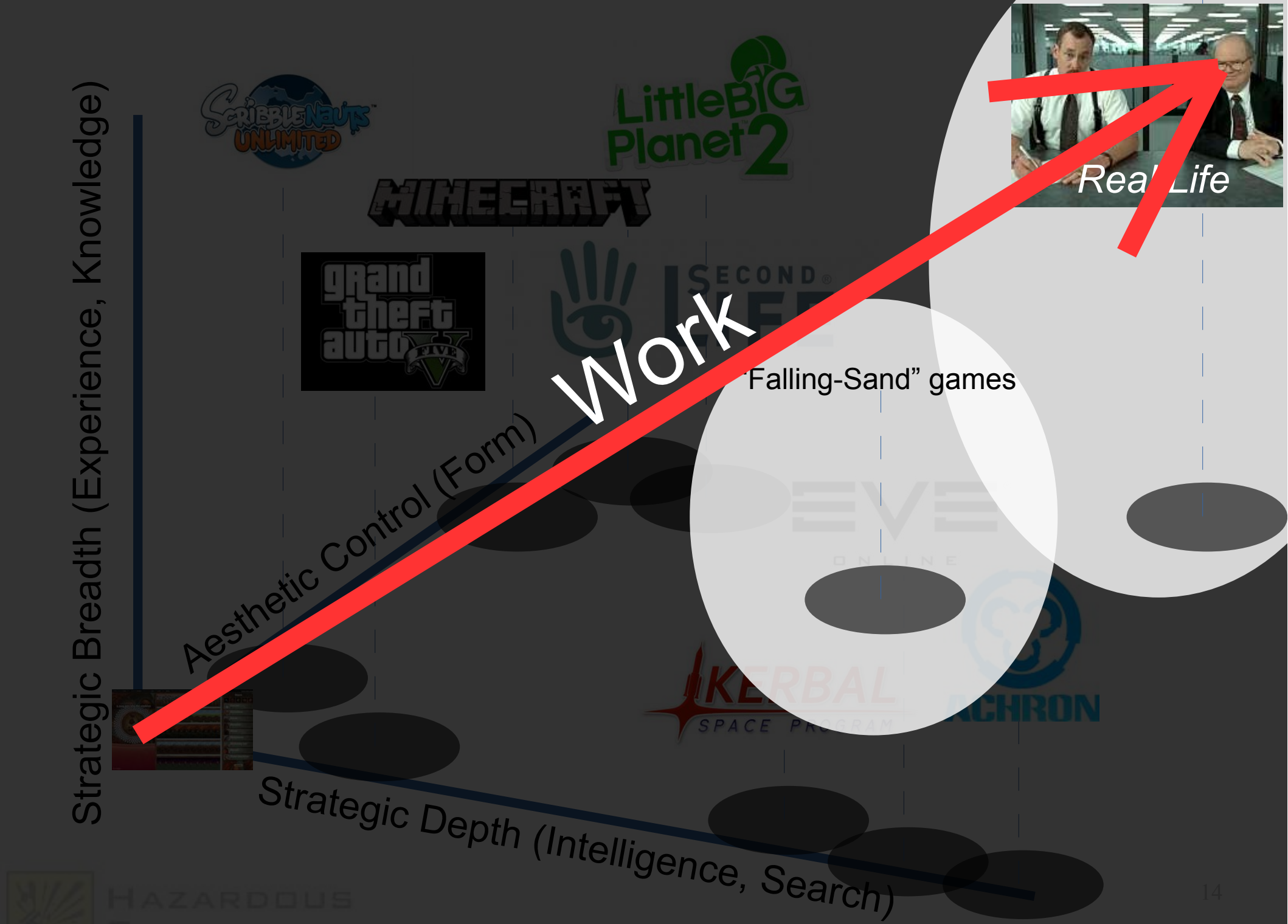

Strategic Breadth (Experience, Knowledge)
Aesthetic Control (Form)
Strategic Depth (Intelligence, Search)
Scribblenauts Unlimited
LittleBIG Planet 2
Minecraft
grand theft auto V
Second Life
Real Life
"Falling-Sand" games
EVE Online
Kerbal Space Program
Achron

"Falling Sand" Games

Powder Game (and 2) (DAN BALL)

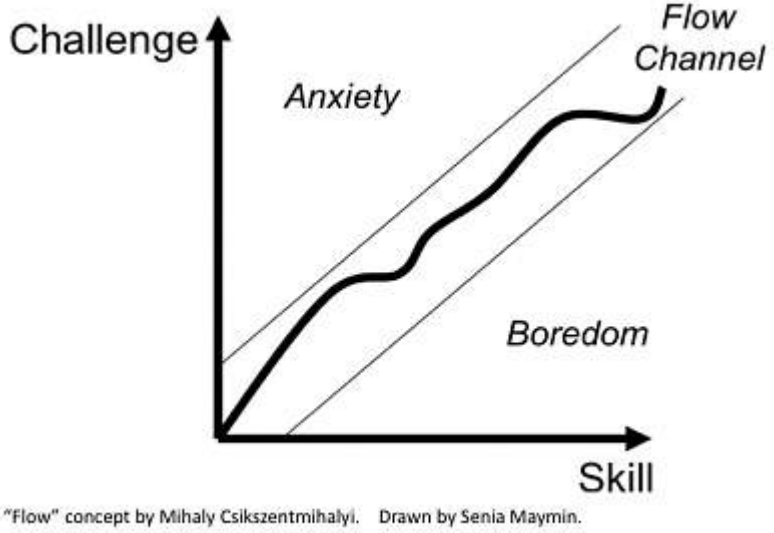


Powder Toy


Strategic Breadth (Experience, Knowledge)
Strategic Depth (Intelligence, Search)
Aesthetic Control (Form)
Work
Real Life
"Falling-Sand" games
Scribblenauts Unlimited
LittleBIG Planet 2
Minecraft
grand theft auto V
Second Life
EVE Online
Kerbal Space Program
Anchron

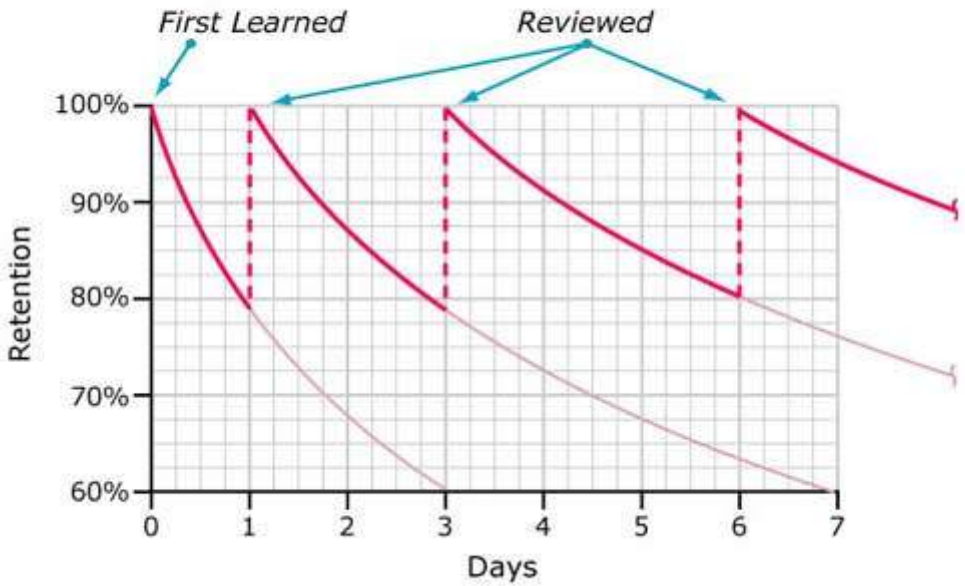
Game Mechanics Breadth, Experience, and Knowledge

Just Cause 2
Map scale



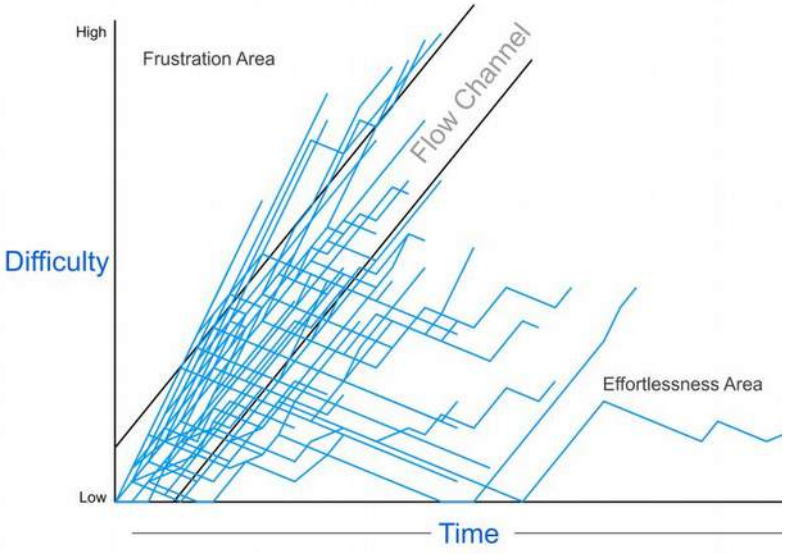
"Flow" concept by Mihaly Csikszentmihalyi. Drawn by Senia Maymin.

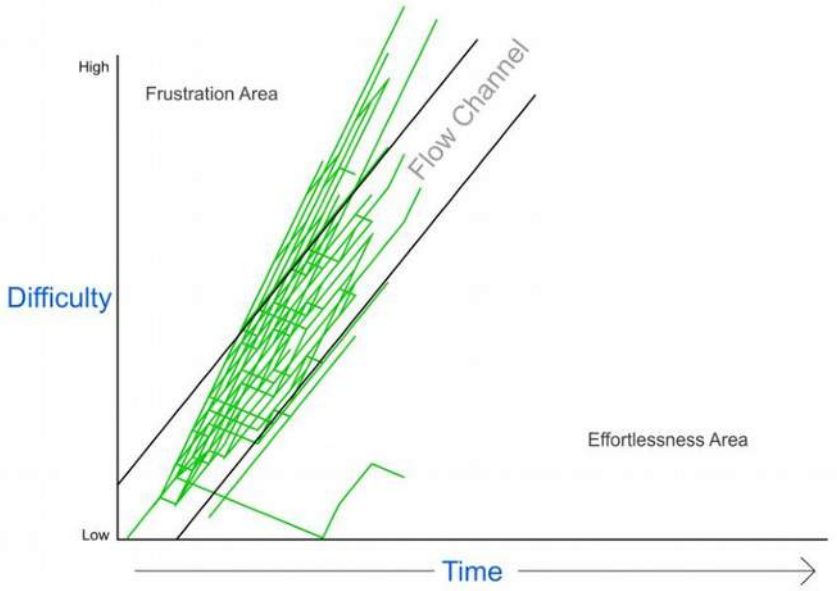
Typical Forgetting Curve for Newly Learned Information



Niel de la Rouviere, Stellenbosch University

Adaptive vs Choice vs Fixed Content





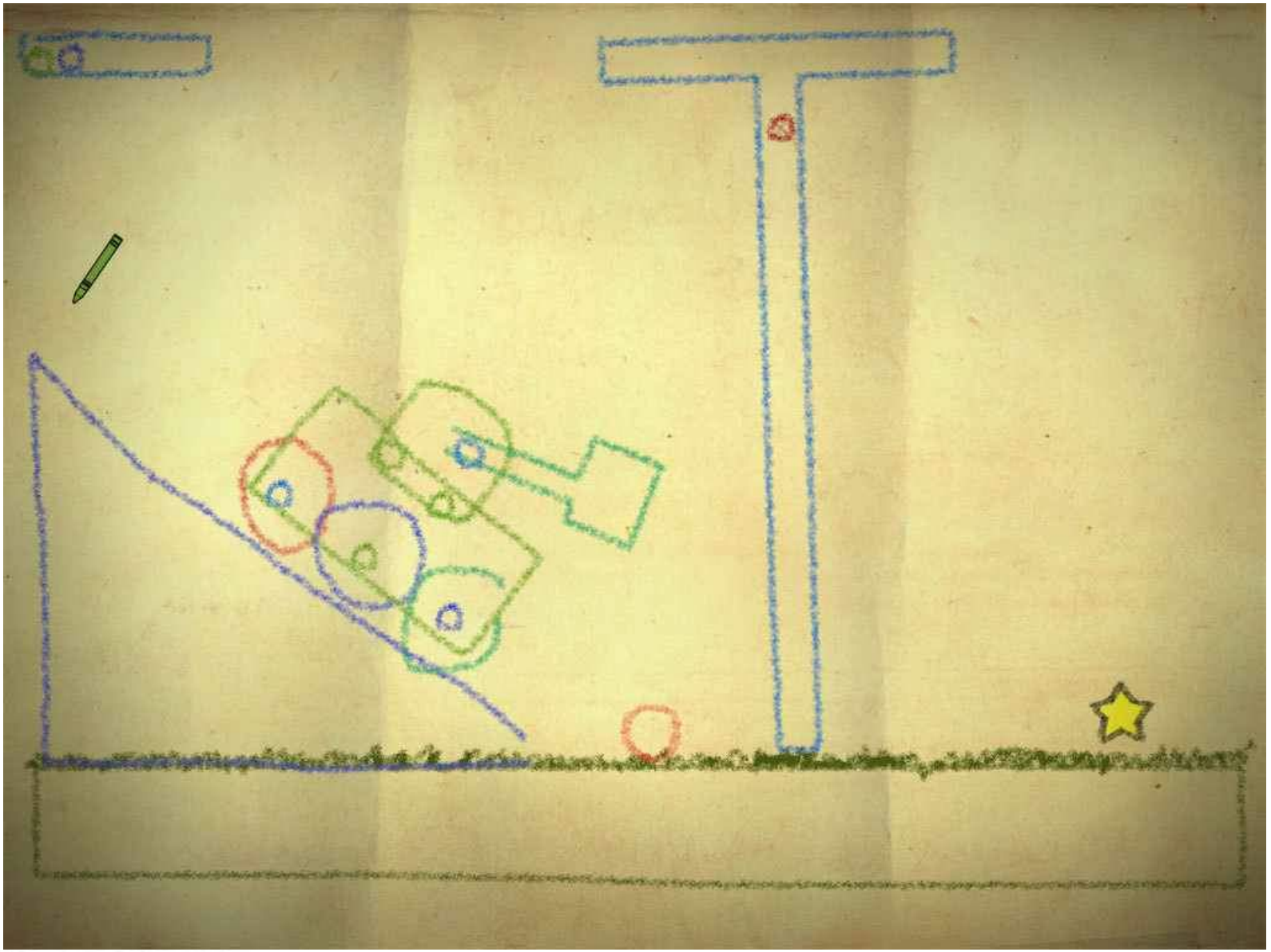
Choice of content

Adaptive content

D. Sharek PhD dissertation at NCSU, 2012. Investigating Real-time Predictors of Engagement: Implications For Adaptive Video Games and Online Training.

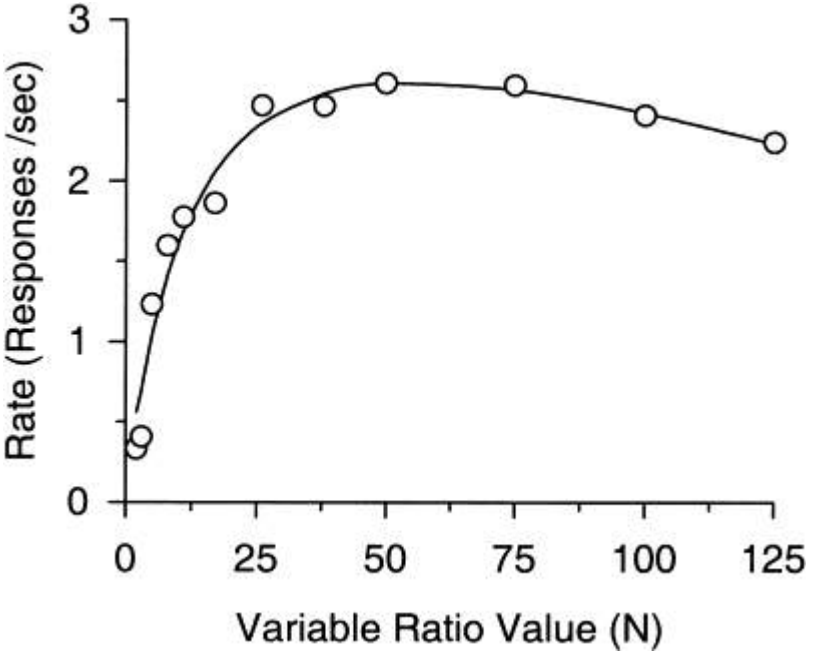
Crayon Physics Deluxe

Petri Purho

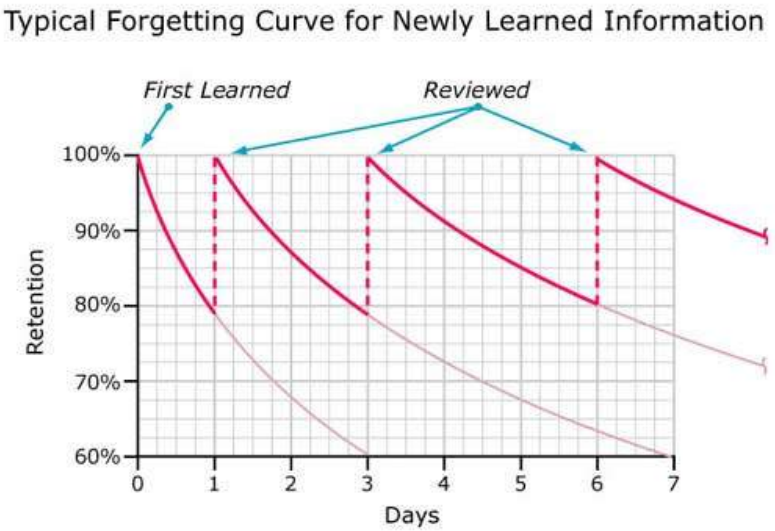


Learning vs Addiction

University of Nebraska, Lincoln



Bizo et al., 2001, Rats don't always respond faster for more food: The paradoxical incentive effect

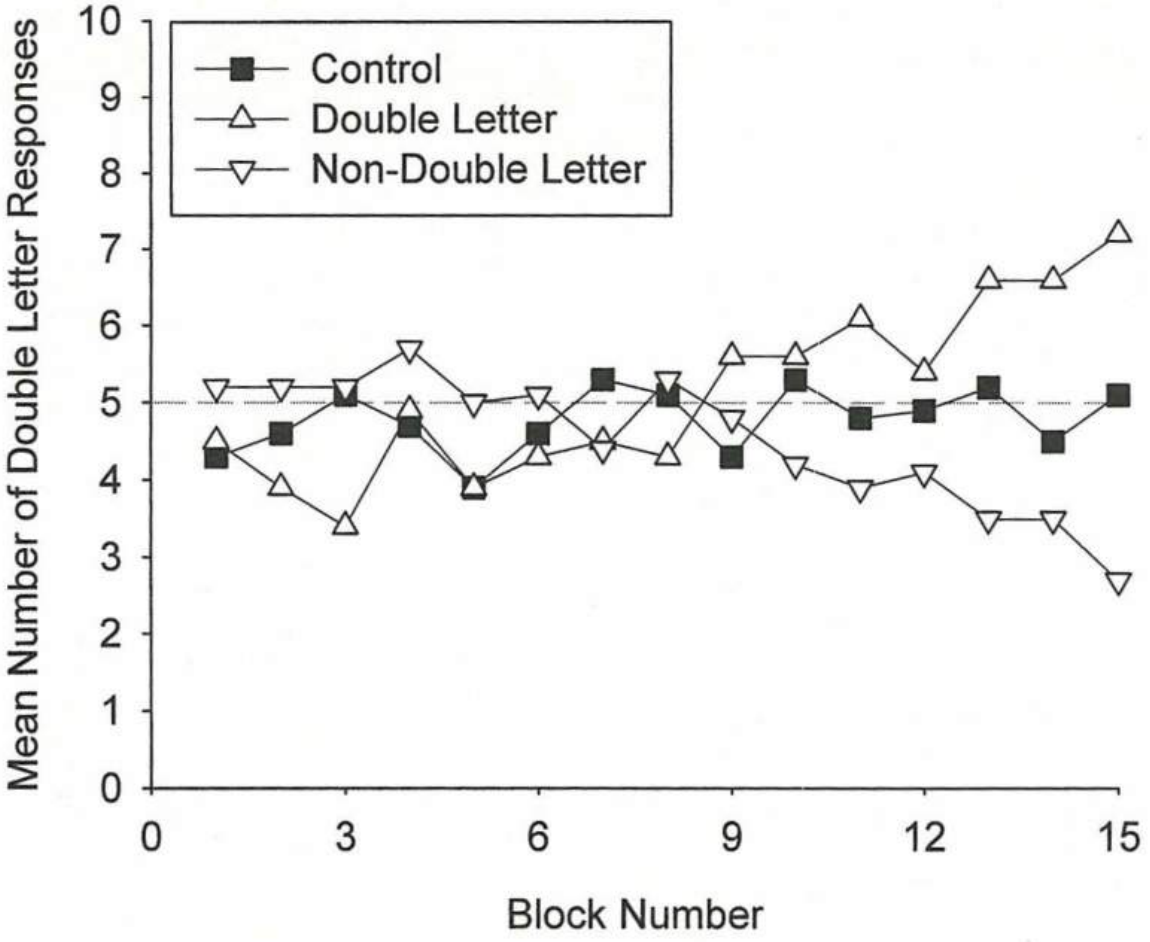


Niel de la Rouviere, Stellenbosch University

← Remember this graph???

Accidental Variable Reinforcement: Good or Bad for Creativity?

Epstein & Skinner, 1982



Bizo & Sweeney, 2005, Use of an ESP Cover Story Facilitates Reinforcement Without Awareness

state of attribute $x \in X$, given a set of observations I can be composed of the individual PDFs of each observation $i \in I$, f_i, as

$$f_{a,I}(x) = \frac{\prod_{i \in I} f_i(x)}{\int_X \prod_{i \in I} f_i(y) dy}. \tag{1}$$

We say that an agent a computes its belief of variable x given the set of observations I as $h_{a,I}(x)$, which is equal to $f_{a,I}(x)$ only for an unbiased agent. Similarly, $h_{a,i}$ represents agent a's computed belief of the PDF of the attribute of observation i. Each observation i has a target of observation, t_i, a situation of observation, s_i, comprising the tuple (t_i, s_i). A target may be another agent or an object.

- **Confirmation Bias**: larger distance between prior belief and new observation j compared to k means diminished impact of observation j:

$$D_{KL}(f_{a,I \cup j} || f_{a,I}) > D_{KL}(f_{a,I \cup k} || f_{a,I}) \\ \wedge D_{KL}(h_{a,I \cup j} || h_{a,I}) < D_{KL}(h_{a,I \cup k} || h_{a,I}) \tag{2}$$

- **Fundamental Attribution Error**: attribute observation to attributes of actor instead of situation (culturally influenced):

$$f_{a,I \cup j} = f_{a,I \cup k} = f_{a,I \cup l} \\ \wedge h_{a,I \cup j} \neq h_{a,I \cup k} = h_{a,I \cup l} \\ \wedge t_j = t_k \neq t_l \wedge s_j \neq s_k = s_l \tag{3}$$

- **Bias Blind Spot**: don't know on biases, so can't correct for them even if they are known ("better than average")

$$f_{a,I \cup j} \neq f_{a,I} \wedge h_{a,I \cup j} = h_{a,I} \wedge t_j = a \tag{4}$$

- **Anchoring Bias**: uneven weighting between observations - certain observations stand out more than others:

$$D_{KL}(f_{a,I \cup j} || f_{a,I}) = D_{KL}(f_{a,I \cup k} || f_{a,I}) \\ \wedge D_{KL}(h_{a,I \cup j} || h_{a,I}) \neq D_{KL}(h_{a,I \cup k} || h_{a,I}) \tag{5}$$

- **Representativeness Bias**: incorrect propagation of probability:

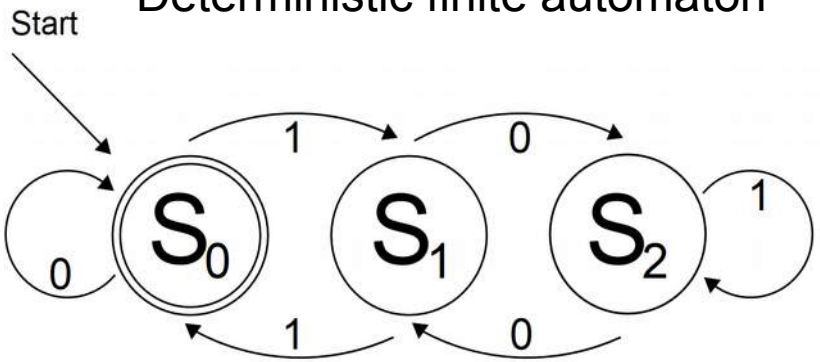
$$h_{a,I}(x) \neq \frac{\prod_{i \in I} h_{a,i}(x)}{\int_X \prod_{i \in I} h_{a,i}(y) dy} \tag{6}$$

- **Projection Bias**: own shortcomings attributed to situation/others rather than self:

$$D_{KL}(f_{a,I \cup j} || f_{a,I}) > D_{KL}(f_{a,I \cup k} || f_{a,I})$$

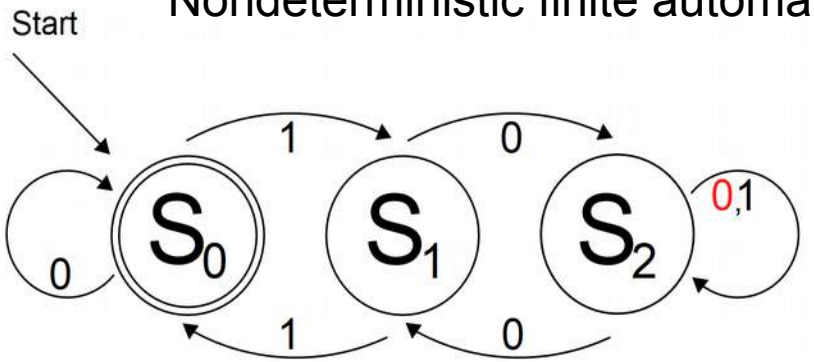
Intro to Computational Complexity

Deterministic finite automaton

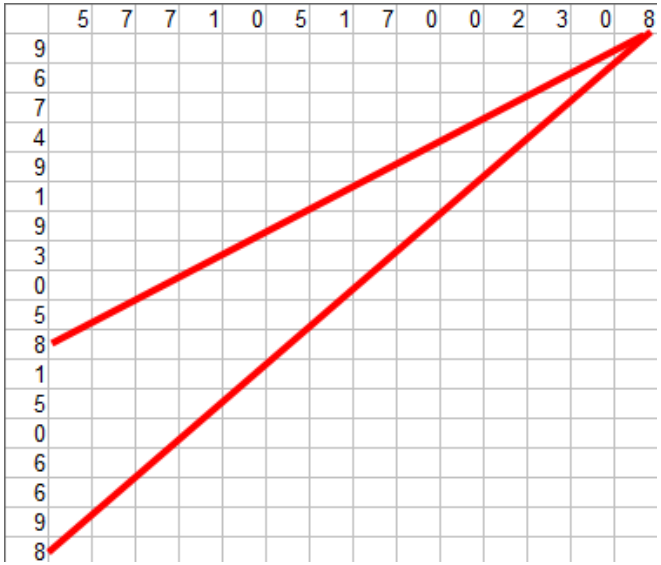


Input: 10101111101010101110101

Nondeterministic finite automaton

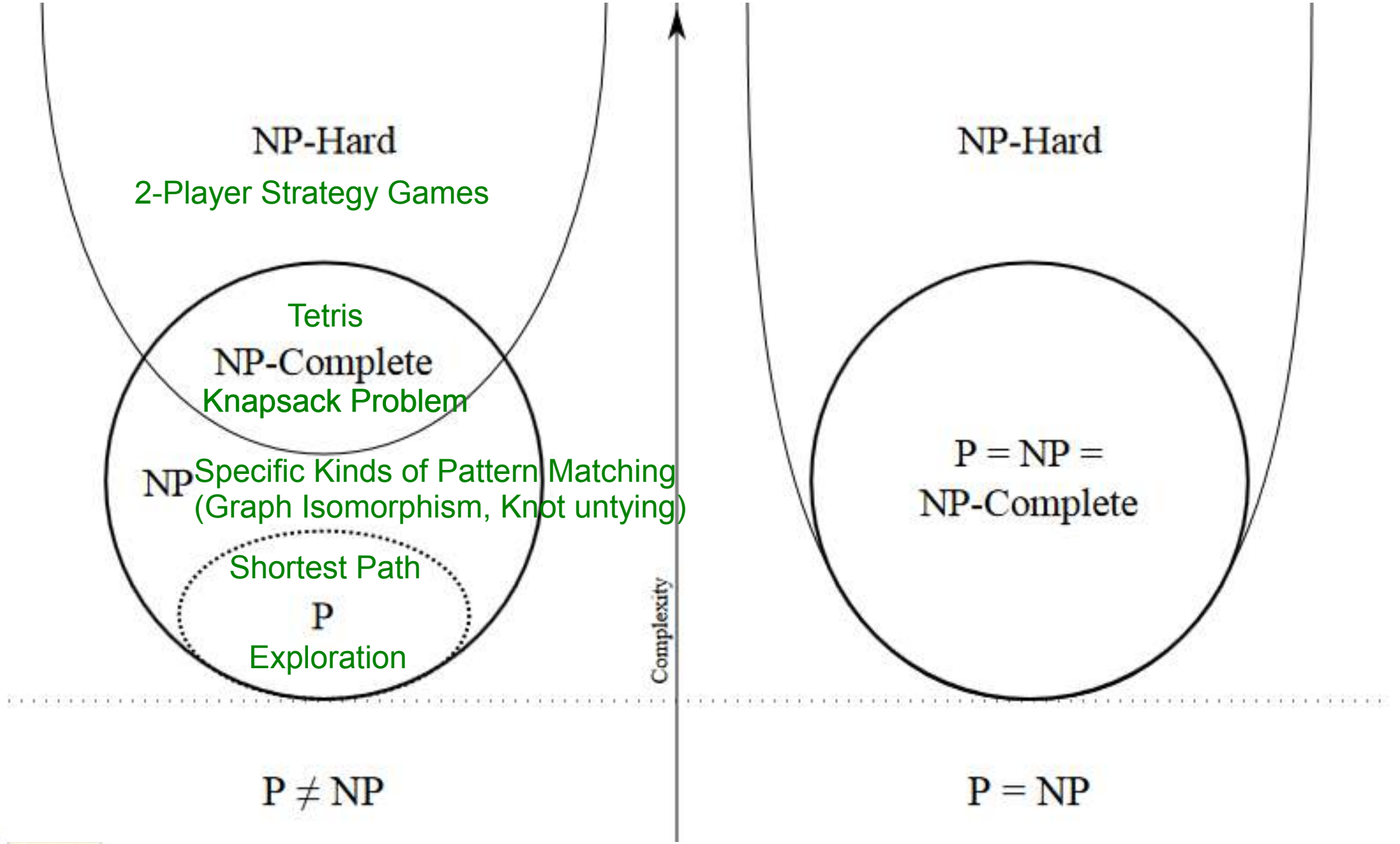


P (polynomial time): max matching



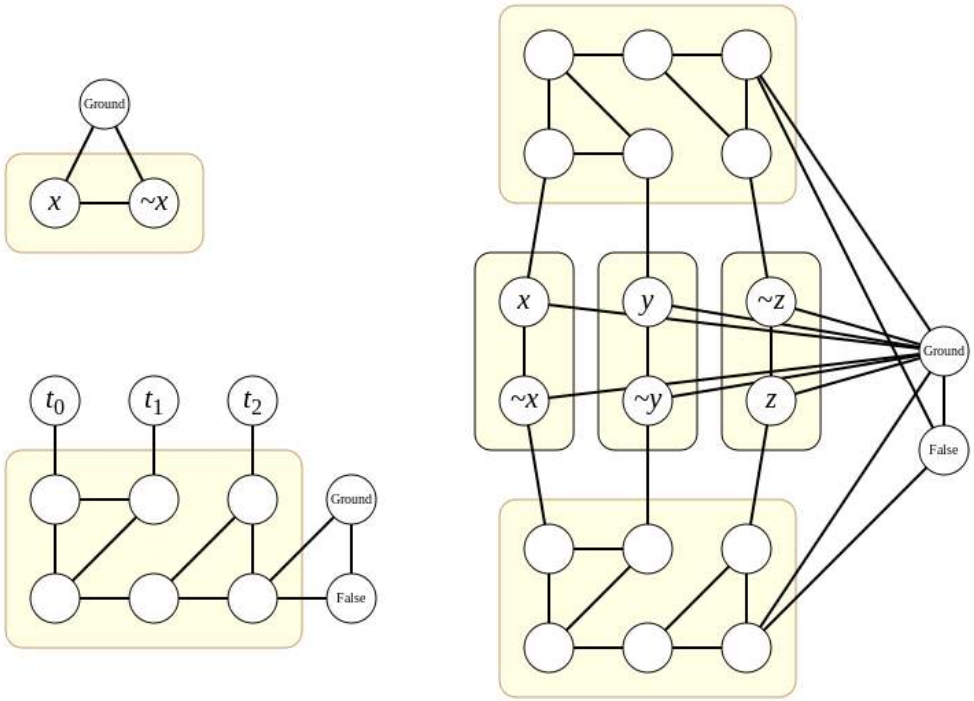
Fewest moves: NP-complete

NP-Hard


NP-Hard
2-Player Strategy Games
Tetris
NP-Complete
Knapsack Problem
NP
Specific Kinds of Pattern Matching
(Graph Isomorphism, Knot untying)
Shortest Path
P
Exploration
Complexity
NP-Hard
P = NP =
NP-Complete
P ≠ NP
P = NP

"Reduction"

Introduction to "Reduction" in Computational Complexity



3SAT → graph 3-color
(x ∨ y ∨ ~z) ∧ (~x ∨ ~y ∨ z)

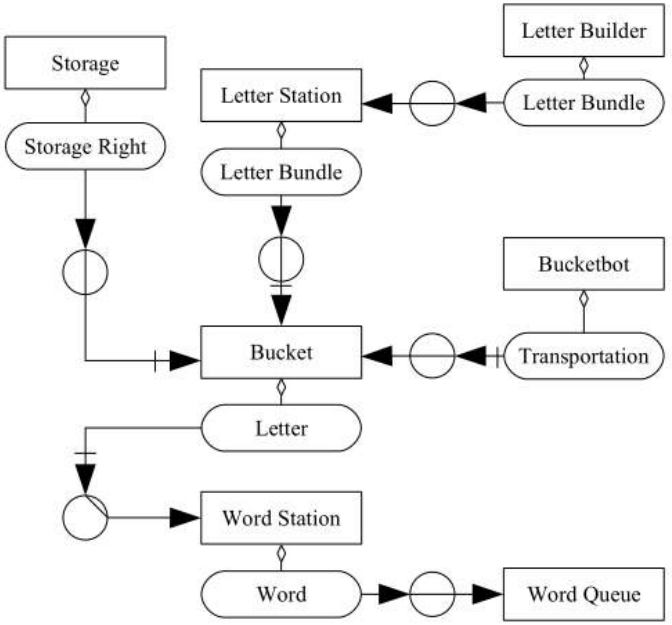
Turing Machine in Little Big Planet
meunierc2008 on Youtube

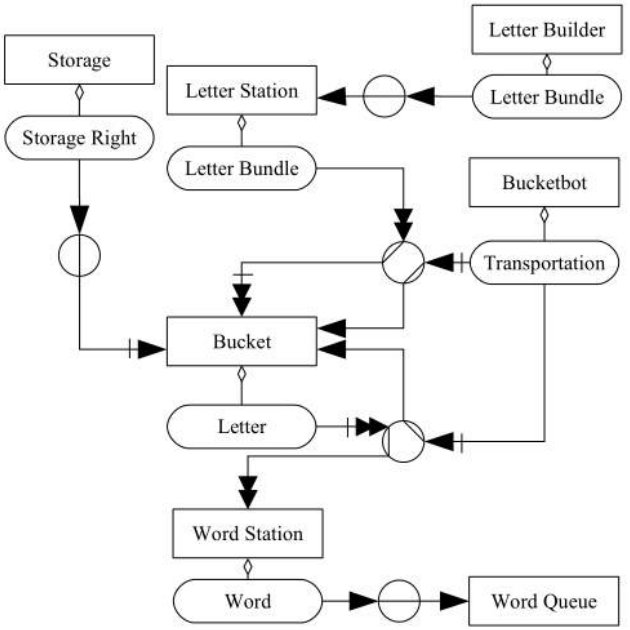
Focus on polynomial time reduction (P)

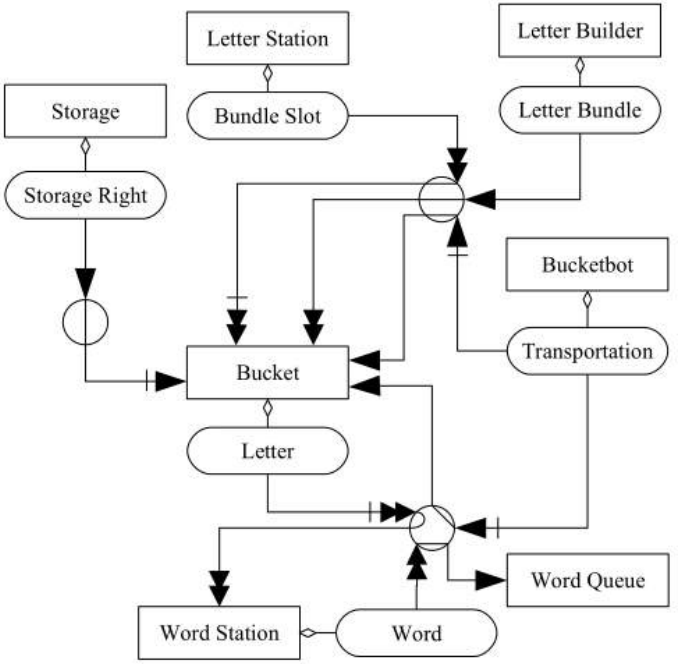
Equivalencies Between Game Mechanics and Computational Problems

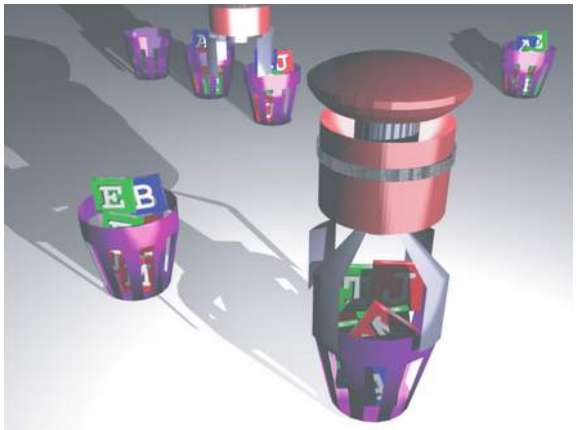
- "Same" problem:
  - Knapsack packing
  - Vertex cover (special units in tower defense, police stations in older versions of SimCity)
  - Hamiltonian path (various kinds of reconnaissance)
- "Same" problem
  - Go
  - Chess
  - Checkers
  - Model checking

Problem Decomposition & Importance of Constraints





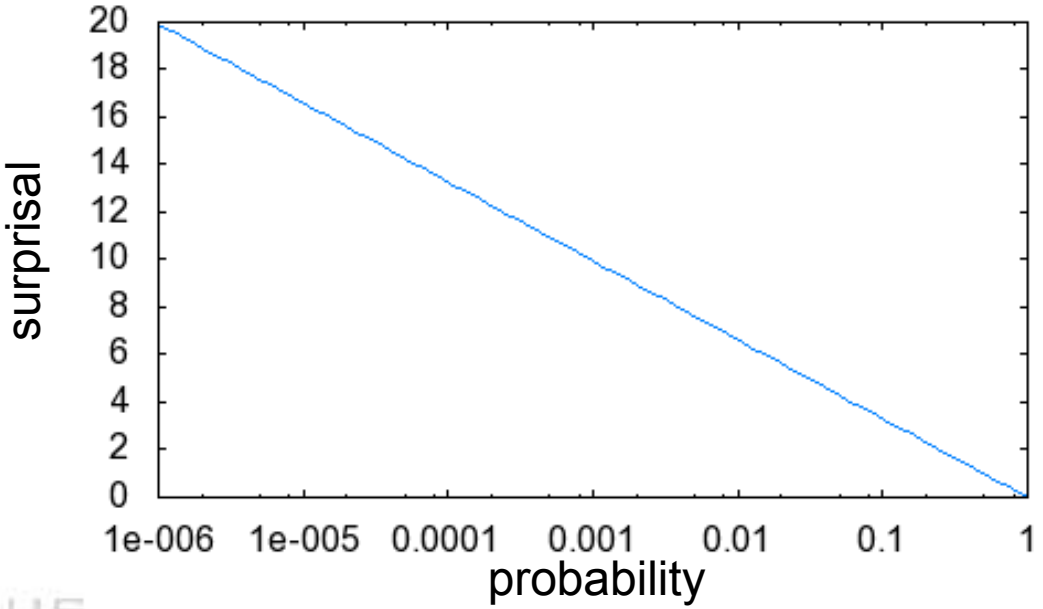




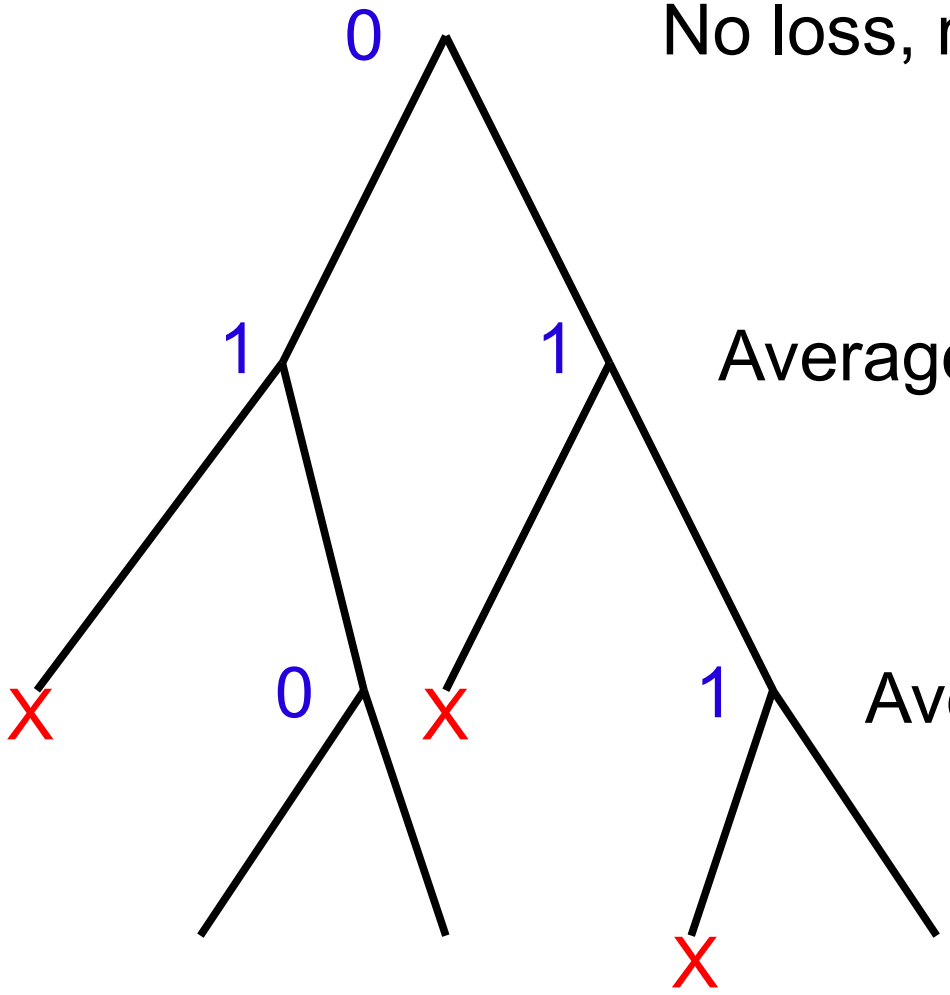
Hazard et al., AAAI Auctions Mech Robotics Wkshp, 2006,
Hazard & Wurman, Working Paper, 2007

Surprisal

- Self-information: information of outcome of random event
- Surprisal: $-\log_2 P(x_i)$



Measuring Difficulty
by Non-Losing Decision Information Rate



No loss, no information

Average 1 bit of information

Average 0.5 bits of information

3 out of 6 paths lose

1.5 bits of total information to win

1.5 bits / 2 steps = 0.75 bits per step to win

Nash Equilibria

Image from Universal Studios

How We Make Rule Systems Now: Games

Scripting

```
var distance;
var target : Transform;
var lookAtDistance = 15.0;
var attackRange = 10.0;
var moveSpeed = 5.0;
var damping = 6.0;

function Update ()
{
	distance = Vector3.Distance(target.position, transform.position);

	if(distance < lookAtDistance)
	{
		lookAt ();
	}
	if(distance < attackRange)
	{
		attack ();
	}
}

function lookAt ()
{
	var rotation = Quaternion.LookRotation(target.position - transform.position);
	transform.rotation = Quaternion.Slerp(transform.rotation, rotation, Time.deltaTime * damping);
}

function attack ()
{
	transform.Translate(Vector3.forward * moveSpeed *Time.deltaTime);
}
```

Unity Script

Behavior Libraries

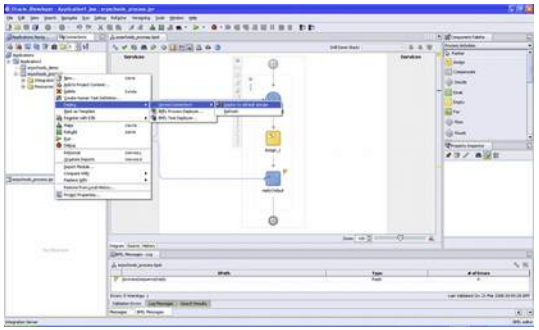
Game Salad

Machine Learning

Black & White

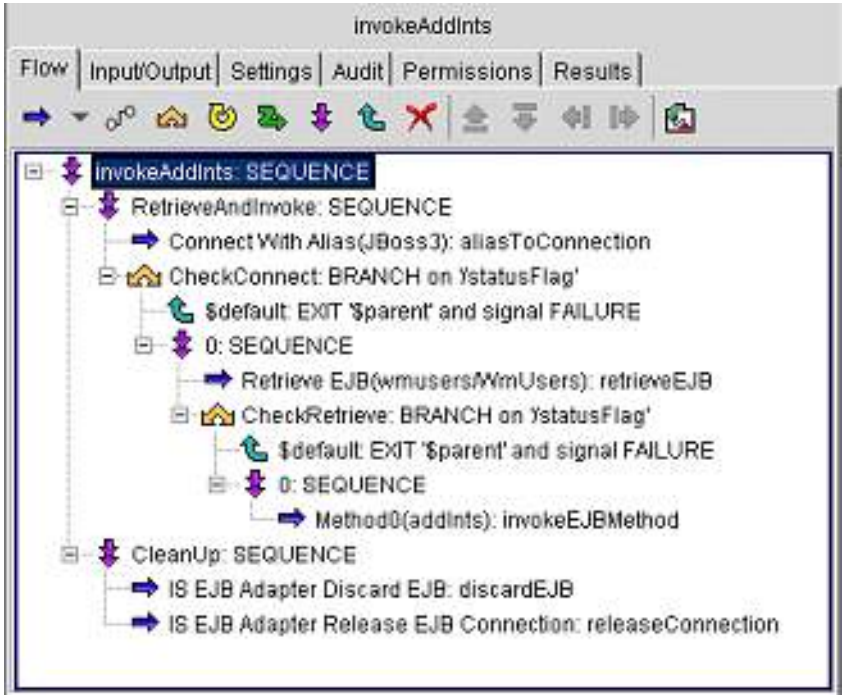
How We Make Rule Systems Now: Business

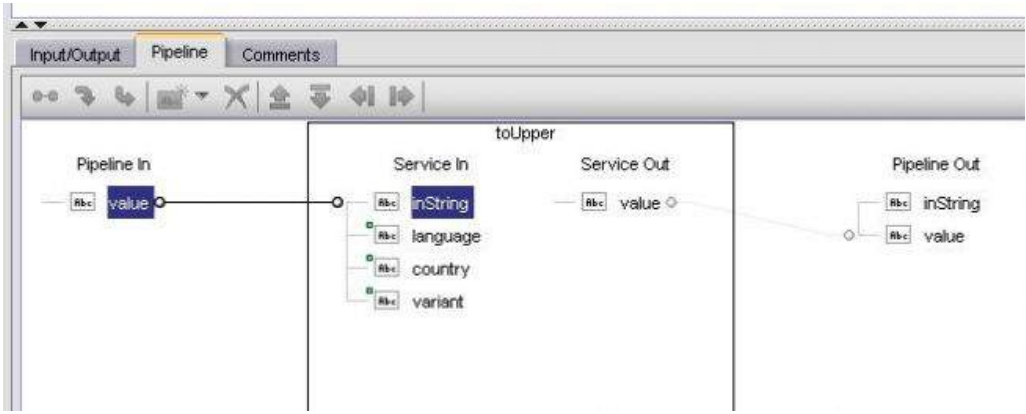
BPEL



```
<?xml version="1.0" encoding="UTF-8"?>
<process
        xmlns="http://schemas.xmlsoap.org/ws/2003/03/business-process/"
        xmlns:print="http://www.eclipse.org/tptp/choreography/2004/engine/Print">

        <!--Hello World - my first ever BPEL program -->

        <import importType="http://schemas.xmlsoap.org/wsdl/"
                location="../../test_bucket/service_libraries/tptp_EnginePrinterPort.wsdl"
                namespace="http://www.eclipse.org/tptp/choreography/2004/engine/Print" />

        <partnerLinks>
                <partnerLink    name="printService"
                                partnerLinkType="print:printLink"
                                partnerRole="printService"/>
        </partnerLinks>

        <variables>
                <variable       name="hello_world"
                                messageType="print:PrintMessage" />
        </variables>

        <assign>
                <copy>
                        <from><literal>Hello World</literal></from>
                        <to>$hello_world.value</to>
                </copy>
        </assign>

        <invoke partnerLink="printService" operation="print" inputVariable="hello_world" />

</process>
```

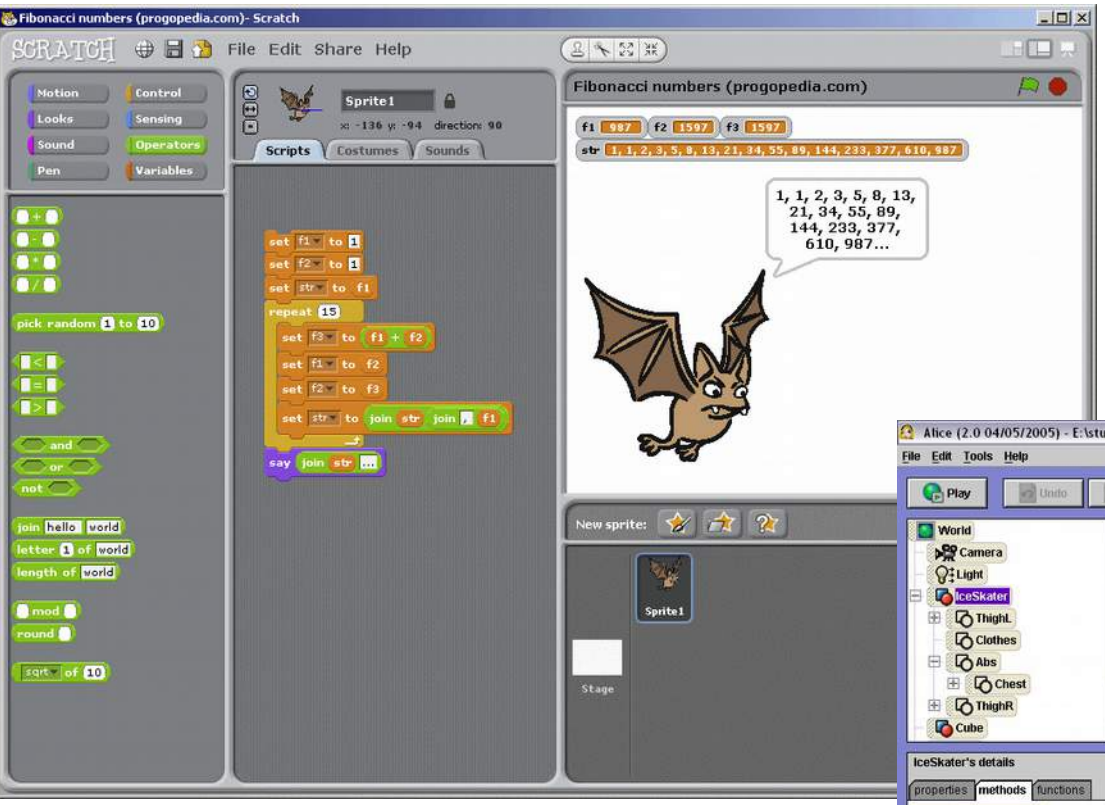
webMethods Flow



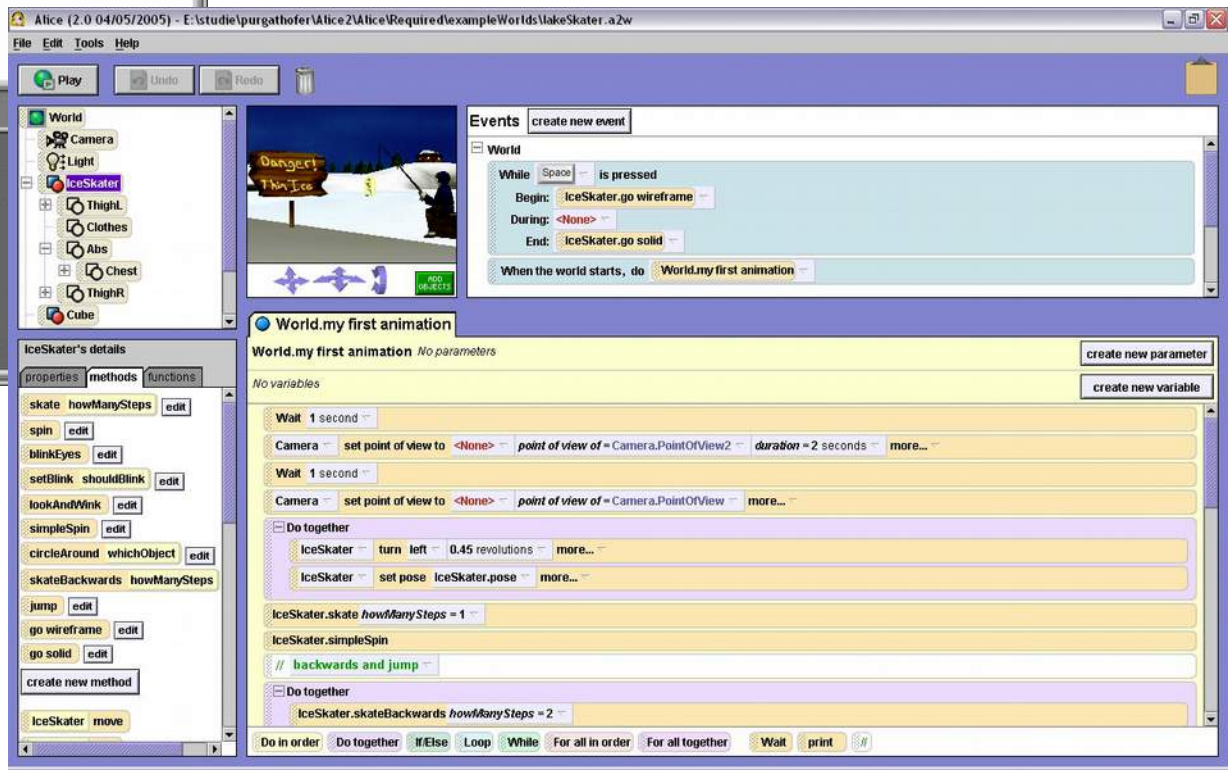


How We Make Rule Systems Now: Novice Programmers

Scratch



Alice

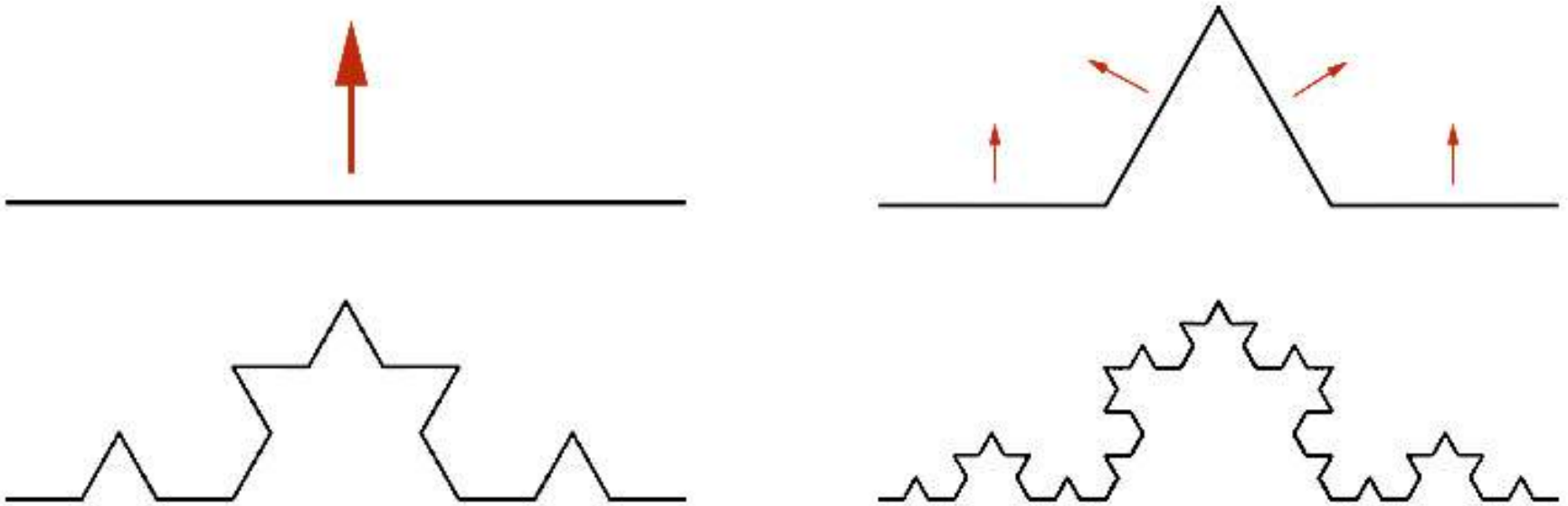


Enhancing Aesthetic Creativity: Procedural Content

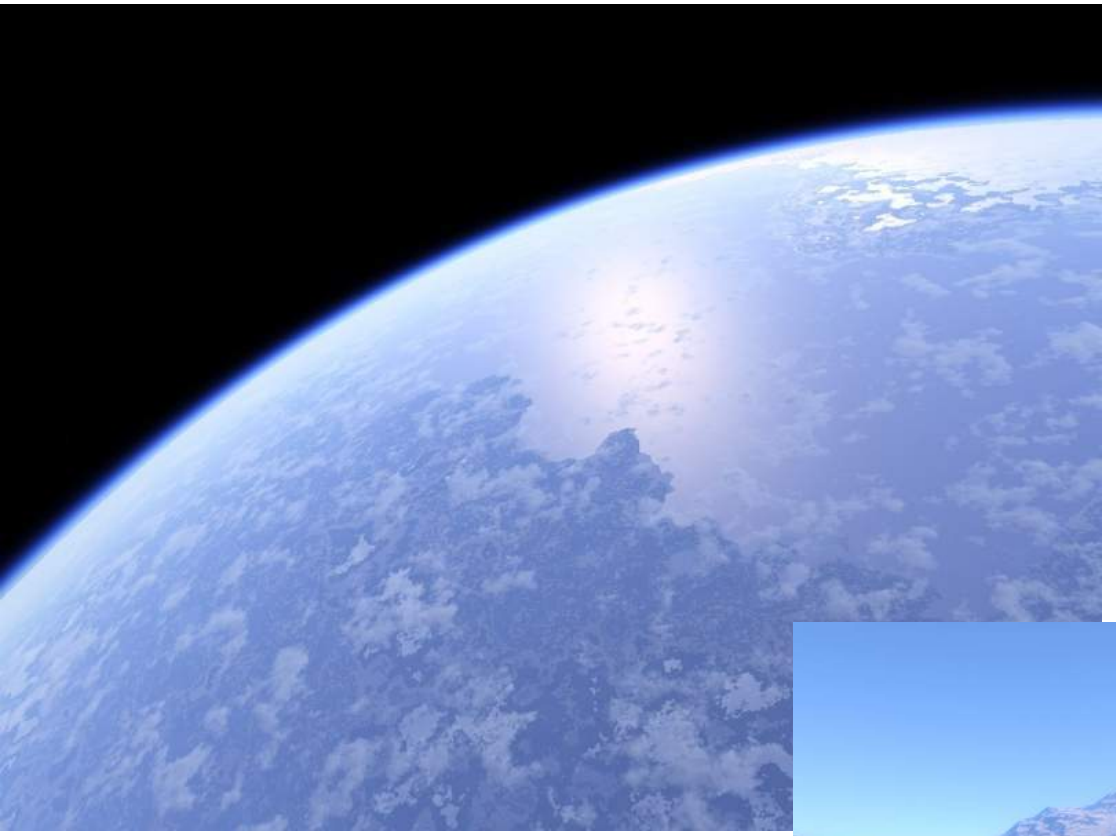
.kkrieger by Farbrausch - 96kb

Procedural Content Example

Koch Snowflake



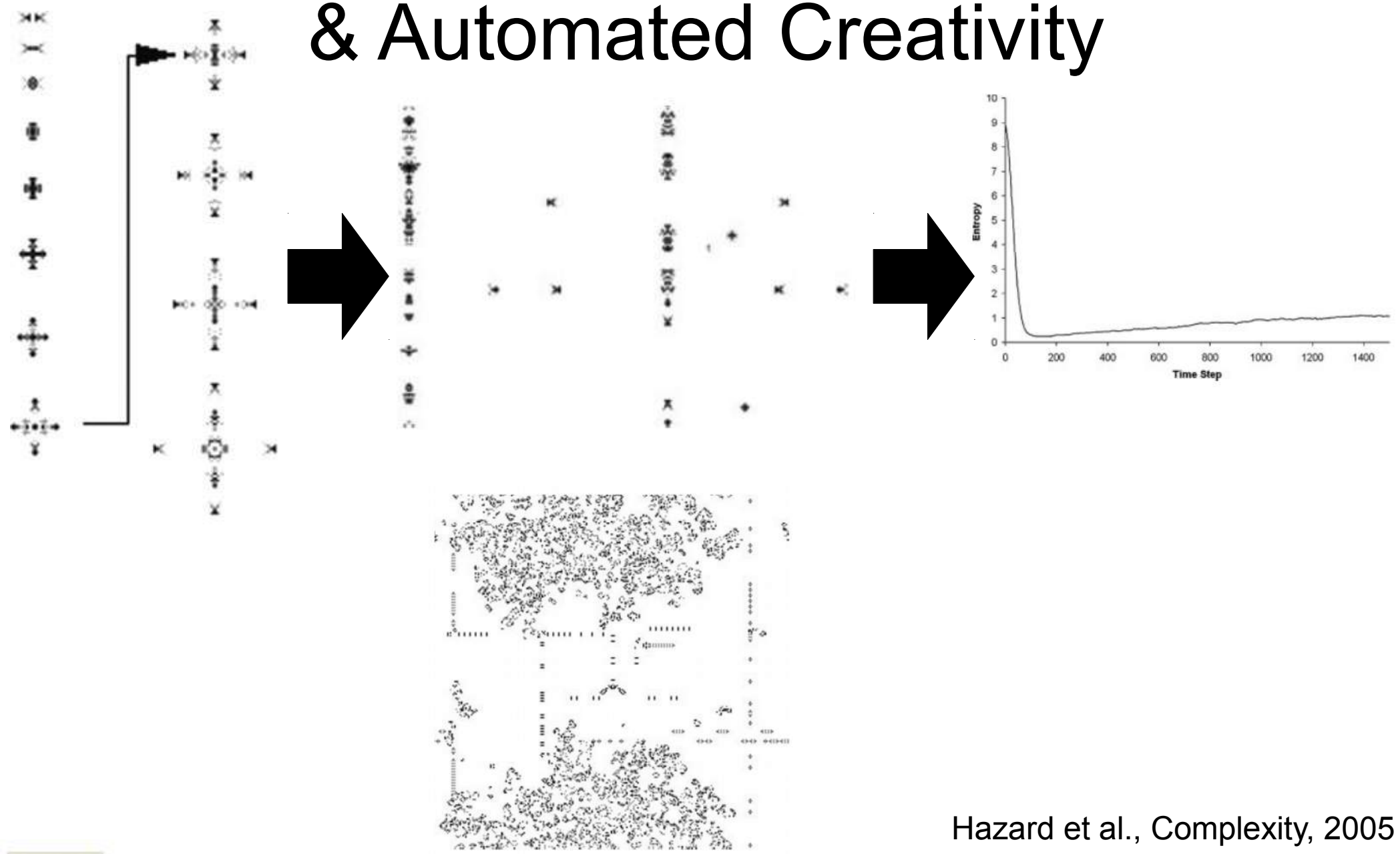
More Advanced Procedural Content



Spore

Infinity (infinity-universe.com)

Emergent Behavior & Automated Creativity



Hazard et al., Complexity, 2005

Measuring Creativity of Something

- Desirability Index (geometric mean of conflicting metrics) in multicriteria optimization:

$$\left(\prod_{i=1}^{n} a_i\right)^{1/n} = \sqrt[n]{a_1\, a_2\, a_3 \ldots . a_n}$$

- Relative Surprisal of solution, KL-Divergence:

$$D_{KL}(P||Q) = \sum_i P(i) \log \frac{P(i)}{Q(i)}$$

- Complexity of solution (Information Entropy):

$$-\sum_i P(i) \log P(i)$$

Psychological Tricks

- Blue to sell (Bellizzi & Hite, 1992)
- Red to intimidate (Elliot et al., 2007)
- Green to be creative (Lichtenfeld et al., 2012)
- Make probability assessments when you're depressed, or ask your friends if they're sad (Korn et al., 2014)

Questions?