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Computational Creativity - an introduction

Geraint A. Wiggins
Professor of Computational Creativity
Queen Mary University of London

Outline

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- Some Big Questions
  - What is Creativity?
  - How can we study Creativity?
  - What is Computational Creativity?

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- Some Big Questions
  - What is Creativity?
  - How can we study Creativity?
  - What is Computational Creativity?
- Some Small Answers
  - way of studying creative systems

Claim

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- Creativity is one of the things that makes humans human

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- If we are to understand ourselves, we need to understand creativity, both as a cognitive and a social phenomenon

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- If we are to understand ourselves, we need to understand creativity, both as a cognitive and a social phenomenon
- Enabling computers to create will
  - make them more useful
  - help us to understand ourselves

So what are we doing?

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- My preferred definition of our field is (Wiggins, 2006):
  - "The support, study and simulation, by computational means, of behaviours which would be deemed creative if exhibited by a human"
    - NB this does not imply that creativity is limited to things that can be done by a human!

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    - NB this does not imply that creativity is limited to things that can be done by a human!
- Updated by Colton and Wiggins (2012):
  - "The philosophy, science and engineering of computational systems which, by taking on particular responsibilities, exhibit behaviours that unbiased observers would deem to be creative."

What is Creativity?

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- Many people think of creativity as the thing that happens when an artist makes a work of art
  - a symphony
  - a painting
  - a sculpture
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  - etc.

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- Most researchers agree that to study things effectively we need to consider creativity as a **process**

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What is Creativity?

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- In the Romantic period of Western culture, "great creators" accrued huge amounts of social capital
- Even in the post-modern era (now) we still "worship" great artists
  - Pablo Picasso
  - Wolfgang Amadeus Mozart
  - Charles Dickens
  - ~~Justin Bieber~~

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  - or at least not very creative

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- Most people would say that most "ordinary" people are not creative
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- We need to deconstruct the Romantic concept if we are to study creativity effectively

Where is Creativity?

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- Creativity (of the kind exhibited by artists) seems to be exhibited only by humans
- Creativity (of the kind exhibited by humans solving practical problems) seems to be exhibited by many mammalian and some bird species
  - New Caledonia Crows use Archimedes' Principle to reach food
  - Chimpanzees build towers to reach food
  - Both these tasks can be done without prior observation, in novel circumstances, so they are probably not innate

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- In each case, creativity seems to be a property of a **well-developed, embodied mind**

What about evolution?

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- Is evolution creative?

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- Is evolution creative?
- Evolution certainly creates things
- But it has no intent and no goal
  - (unless we appeal to mysticism)
  - which makes it different from human creators

An approach

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- Can we apply reductionist science to creativity, as a phenomenon, and thereby understand it better?
  - (yes)

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- Can we apply reductionist science to creativity, as a phenomenon, and thereby understand it better?
  - (yes)
- Attempt to divide the phenomenon up into different parts and see how they work separately
  - then put them back together

Early attempts

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- Wallas (1926), Koestlter (1964), Guilford (1967), Csikszentmihalyi (1976) all propose "theories of (human) creativity" which attempt to break down a creative process into smaller blocks

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- They are very much behavioural descriptions
  - theories do not really make predictions
  - Koestler's at least proposes a cognitive mechanism ("bisociation") which allows creativity to take place
    - this was reinvented and developed into conceptual blending (Turner & Fauconnier, 1995)

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  - Koestler's at least proposes a cognitive mechanism ("bisociation") which allows creativity to take place
    - this was reinvented and developed into conceptual blending (Turner & Fauconnier, 1995)
- However, there is nothing in any of the early creativity theories that allows us to test them empirically

Boden: The Creative Mind (1990)

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- The only (?) effective attempt to apply reduction to creativity
  - a conceptual space of created artefacts
  - evaluation
  - novelty
- Apparently similar to AI search - but NOT THE SAME THING
- Key idea: separate out the production of the artefact from its novelty and value

Novelty and Value

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- Both value and novelty are relative concepts, to
  - the creator
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  - the creator
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- But we may imagine creative processes that are universal in terms of the conceptual space

The conceptual space

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The conceptual space

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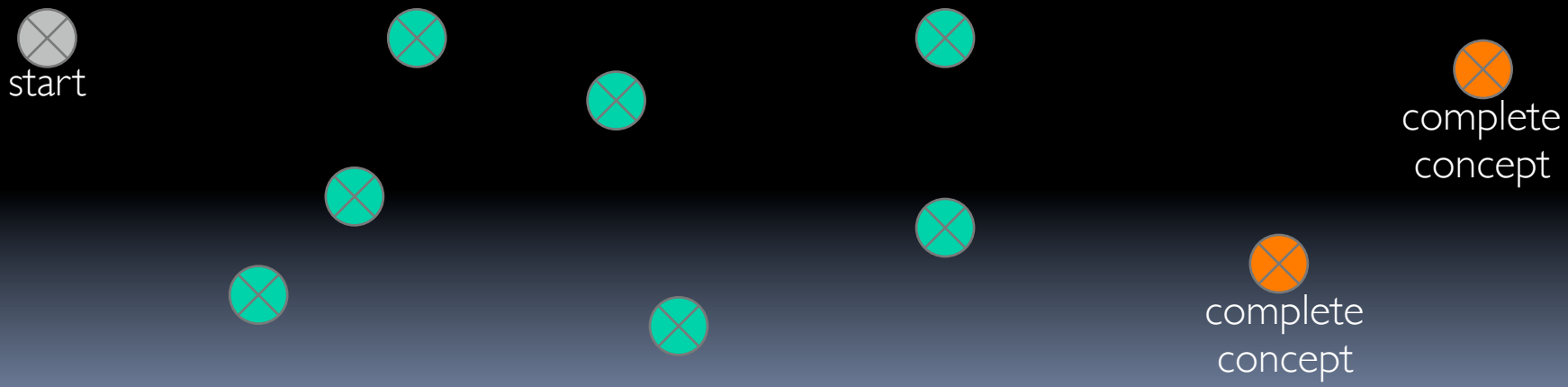
- Creative activity is cast as the discovery of *concepts* in a *conceptual space*



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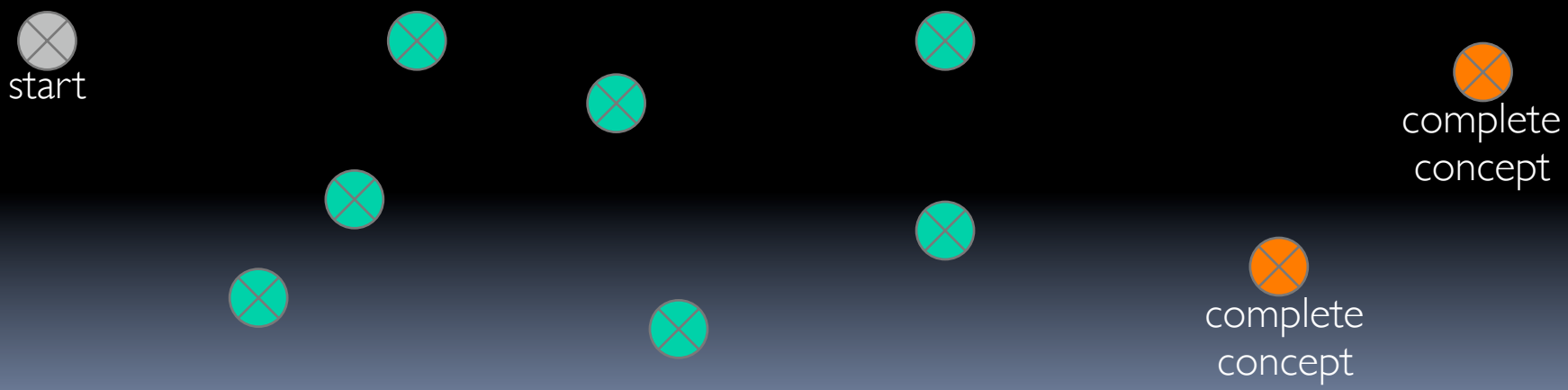

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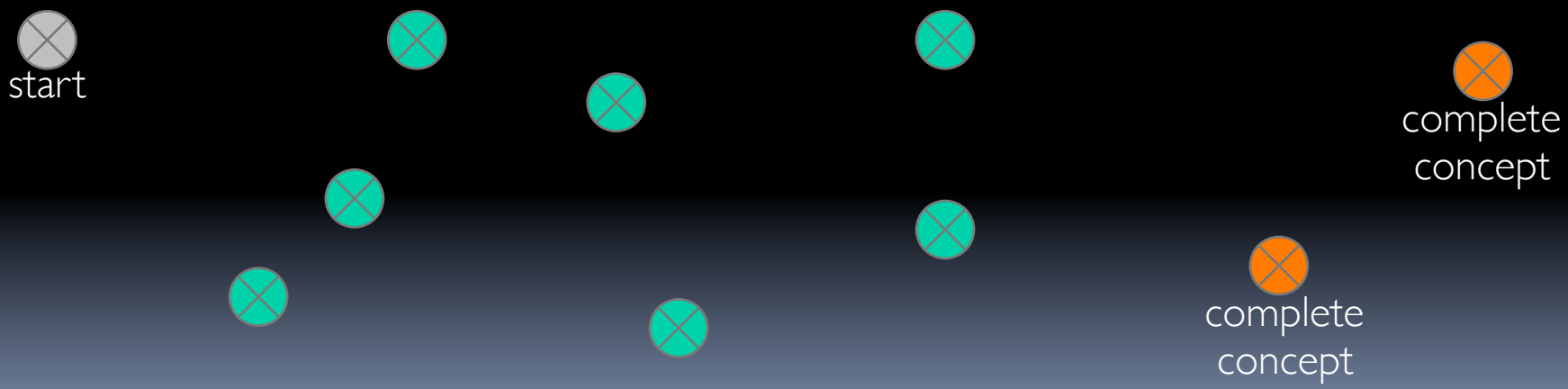

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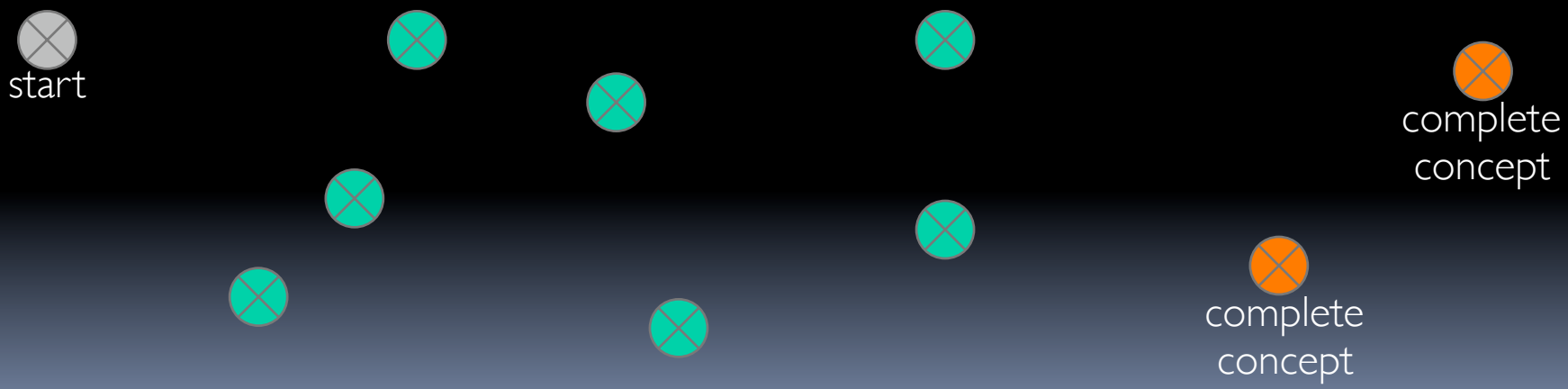

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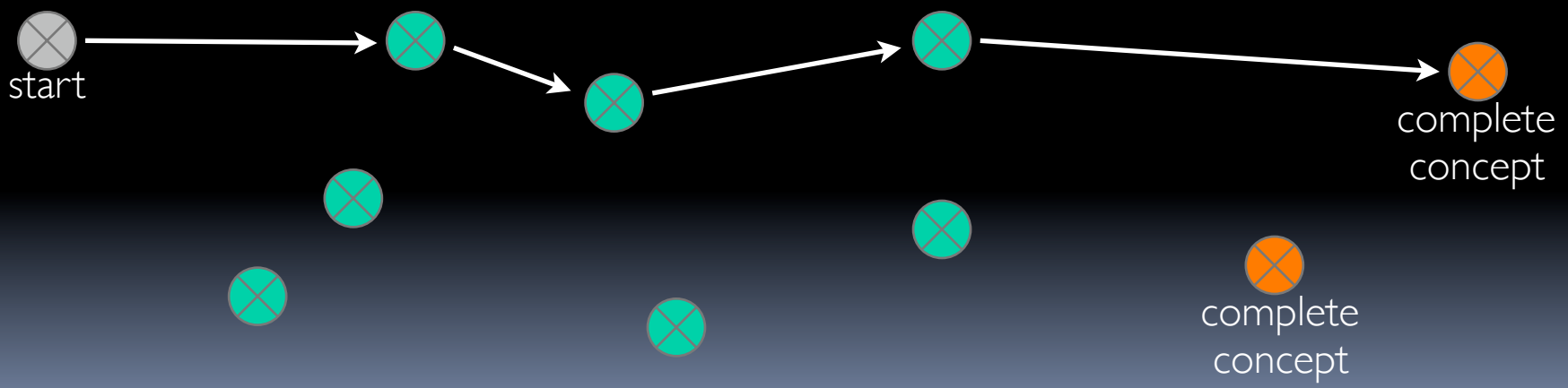

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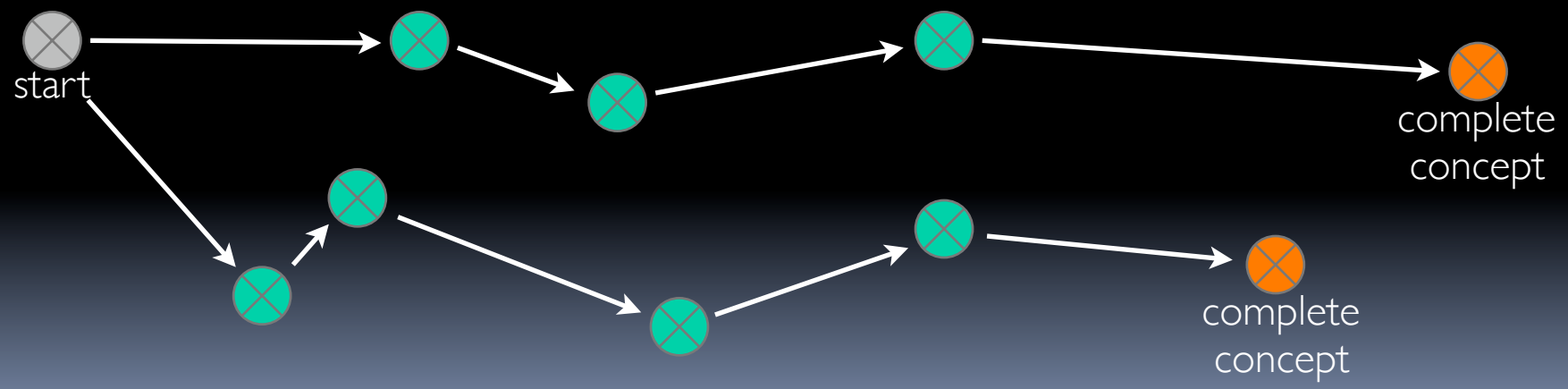

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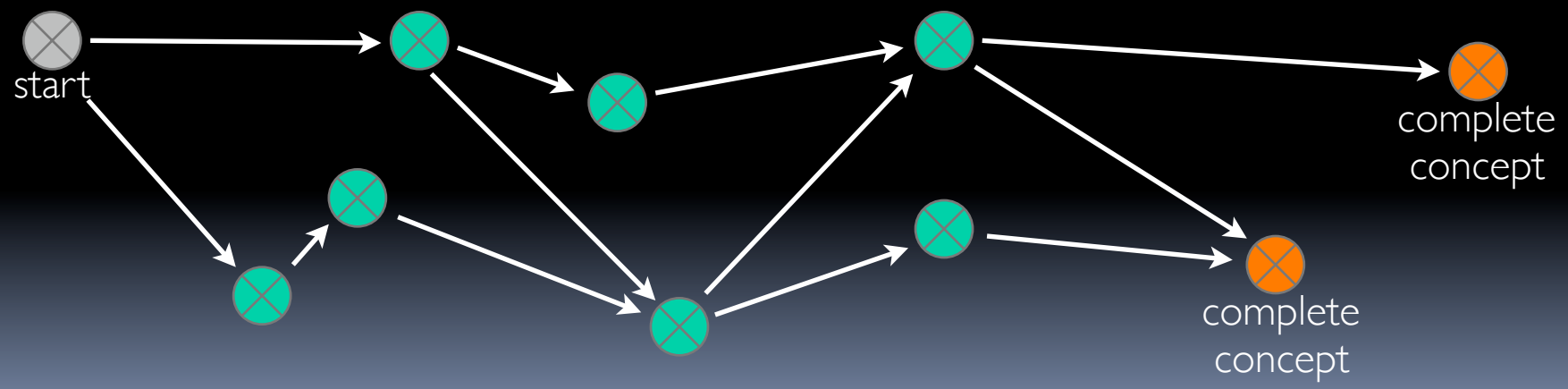

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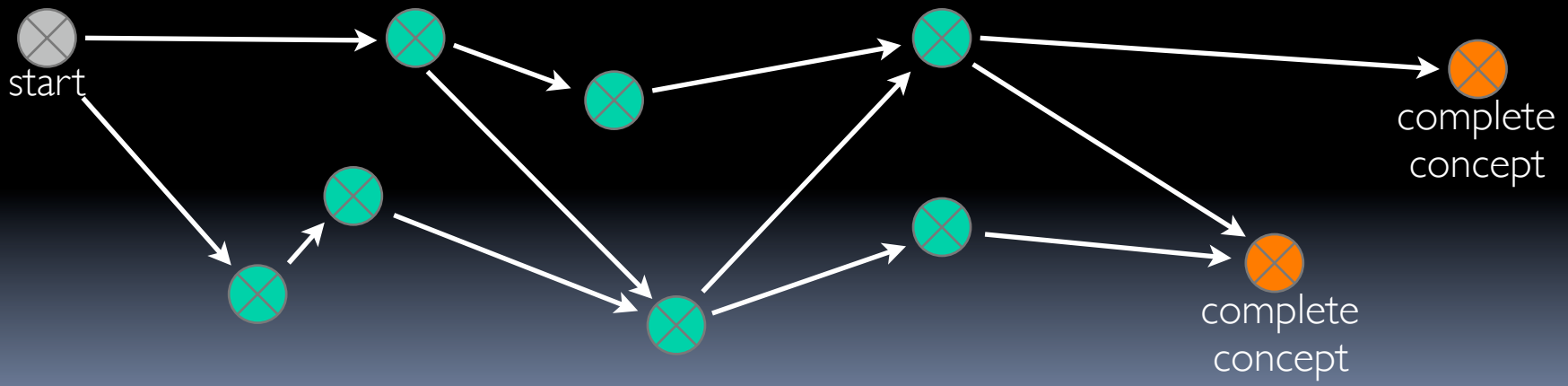
- *Exploratory creativity* is defined as the action of searching the conceptual space for a new concept
- This is an *abstraction* - no strong claim that it works this way in minds/brains



Transformational creativity

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- Boden suggests that transformational creativity is more significant than exploratory creativity, because it is in a sense "bigger thinking"
- Bundy (1998) and Wiggins (2006b) argue against this, as an overly simple definition

Reasons why not

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- "A symbolic system cannot create new concepts"
  - weighted semantic networks allow us freely to define new concepts in terms of old ones
  - conceptual blending allows us to create new semantic structures directly
  - geometrical representations of meaning allow arbitrary interpolation between concepts (e.g., Gärdenfors, 2000)
    - though we do need to think carefully about what the resulting representations mean!!

Reasons why not

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- "A system which is exploring a search space defined by a representation is not being creative"
  - not necessarily true: it depends on the expressive power of the representation
  - creating an artefact by *explicit mechanistic inference* doesn't make doing so any less creative
  - cognitively speaking, creative insight does not "feel" like enumeration
    - but such introspection is almost always misleading

Reasons why not

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- "Non-symbolic systems generalise via a simple mathematical process, which is not creative"
  - There is no evidence that the human mind does not create in this way
  - There are suggestions (e.g., Kanerva's sparse distributed memory) that this is exactly how the human mind creates
  - Anyway, interpolation and generalisation may be a perfectly good model of creativity

Formalising Boden's model

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- Partial and complete concepts are represented as points in the space
- Each dimension of the space represents a feature of the domain
- (So each point denotes a set of property/value pairs)

Defining a conceptual space

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- $\mathbf{C} \subset \mathbf{U}$

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- We also need a null concept, $\top$

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- Let us also allow another set of rules, **T**, describing our creative agent's method for exploring **C**

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- We will need a more complex interpreter, $\langle\!\langle .,.,. \rangle\!\rangle$, which, given three sets of rules in **L**, will return an effective procedure for computing an ordered set of (partial) concepts, $\mathbf{c}_{out}$, from another, $\mathbf{c}_{in}$

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$$\mathbf{c}_{out} = \langle\!\langle \mathbf{R}, \mathbf{T}, \mathbf{E} \rangle\!\rangle (\mathbf{c}_{in})$$

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- Note that $\mathbf{e_C}$ may be a subset of **C**
- This is because a creative agent's exploratory technique, as captured by **T**, need not be strong enough to discover all the concepts which are actually admissible under **R**
- Or $\mathbf{e_C}$ may intersect **C**, producing some acceptable and some unacceptable concepts

An exploratory creative system

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U	The universe of all concepts
L	A language for expressing rules and concepts
$[\![.]\!]$	A testing interpreter (for **R**)
$\langle\!\langle .,.,.,. \rangle\!\rangle$	An enumerating interpreter (for **R**, **T** and **E**)
R	A set of rules defining a conceptual space, **C**, in **U**
T	A set of rules allowing traversal of **U** (around **C**)
E	A set of rules evaluating concepts found using $\langle\!\langle .,.,.,. \rangle\!\rangle$

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- Transforming **T** is transforming the creative agent's personal method

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- So **L*** is now the universe in which we are searching
- We can describe **L** (and **L***) with a metalanguage $\mathbf{L_L}$

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Transformational creativity

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- To capture the exploration of the rule space, we need some constraints on what is syntactically well-formed, $\mathbf{R_L}$
- We also need to define the search strategy, $\mathbf{T_L}$
- If we use the metalanguage $\mathbf{L_L}$ as before for these specifications, we can use the same interpreters as before, $[\![.]\!]$ and $\langle\!\langle .,.,.,. \rangle\!\rangle$

Transformational creativity

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- So transformational creativity is exploratory creativity at the meta-level of conceptual spaces
- $\mathbf{E}_{\mathbf{L}}$ may be characterised in terms of **E** (see Wiggins, 2006a, for how)

On failing to create...

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- We are now in a position to examine the behaviour of creative systems
- The different components of the descriptions interact, and how they interact can tell us useful information
- Now, we discuss ways in which a system can fail to create
- Therefore, a creative system can introspect about how to improve itself

Uninspiration

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- *Uninspiration* is the inability to produce valued outputs
- There are three kinds of uninspiration:
  - Hopeless
  - Conceptual
  - Generative
- It is useful to know about uninspiration, because it can act as
  - a "well-formedness" check
  - a trigger to transform a creative system in one way or another

Hopeless Uninspiration

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- The simplest case of uninspiration is where there are no valued concepts in the universe:

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- It is a property which we should attempt to disprove of any creative system, *a priori*

Conceptual Uninspiration

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- Conceptual uninspiration can be used as a cue to encourage *aberrant* behaviour

Generative Uninspiration

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- *Generative uninspiration* is where a creative agent's technique, **T**, causes it to miss the valued members of the conceptual space:

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- It can act as a trigger for transformation of **T** (or **R**)

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- *Aberration* is the production of new concepts which are not in the existing conceptual space (that is, deviation from the expected)
- There are three kinds of aberration:
  - Perfect
  - Productive
  - Pointless

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- Aberration happens when a creative agent finds concepts which are valued, but which are not in the conceptual space
- This is why value (**E**) needs to be represented distinctly from acceptability (**R**)
- In the CSF, this means that

$$\langle\!\langle \mathbf{R}, \mathbf{T}, \mathbf{E} \rangle\!\rangle^{\diamond}(\{\top\}) \setminus [\![\mathbf{R}]\!](\mathbf{U}) \neq \varnothing$$

Perfect Aberration

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- Perfect aberration is the case where

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- This, in most cases, will be a cue to transform **R** so that it includes the new concepts

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- This, in many cases, may be a cue to transform **R** or **T** or both

Pointless Aberration

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- Pointless aberration is characterised by

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- This is a cue to transform **T** but not **R**

Reflection and transformational creativity

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- Is this what artists/musicians/scientists do when they (eg) consciously change style?
- Just because we can use the CSF to model creative systems, it doesn't mean that all creative systems have to work by search
- We can usefully conceptualise/model a process as a search mechanism in the abstract even if that is not how it actually works

An important question

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- What is the difference between Good Old-Fashioned AI Search and Computational Creativity based on the Boden/Wiggins model?

GOFAI Search

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GOFAI Search

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- Given an agenda **S** (a sequence of states):
  1. If **head**(**S**) is a solution, stop.
  2. Remove **head**(**S**) from **S** giving remainder **S'**
  3. **expand**(**head**(**S**)) giving **S"**
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- For Depth-First Search, **merge** = **prepend**
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- For Best-First Search, Hill-climbing, A, A*, **merge** = **append+sort**

GOFAI Search

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GOFAI Search

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- Key Features:
  - Representation: can represent all and only output configurations of problem (closed world)
  - Solution detector: Boolean test for (a representation of) a solution
  - Heuristics allow control of search for best one(s)
    - calculate "quality" of solutions
    - calculate "distance" from nearest solution
    - combination of these

Similarities

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Similarities

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- GOFAI search vs. CSF
  - Representation syntax ≃ Rules of **R**
  - Search space ≃ Conceptual space
  - Algorithmic framework ≃ Algorithmic framework
  - Heuristics ≃ Traversal (**T**) and/or Value (**E**) Rules
  - Agenda (**S**) ≃ Current expansion of space ($\mathbf{c_{in}}$)

Differences

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- Representation: closed vs. open world (**C** vs **U**)
  - admits "discovery" of solutions not envisaged by system designer

Differences

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- Representation: closed vs. open world (**C** vs **U**)
  - admits "discovery" of solutions not envisaged by system designer
- Algorithmic framework: single vs. multiple operands
  - admits more complex (powerful?) search algorithms, e.g., GA, blending

CSF > GOFAI Search

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CSF > GOFAI Search

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- GOFAI search can be implemented in the CSF

CSF > GOFAI Search

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- GOFAI search can be implemented in the CSF
- The CSF cannot be implemented as GOFAI search
  - (unless, in both cases, we disingenuously jump to a meta-level)
  - The CSF is therefore more expressive than the GOFAI search framework
  - So Boden's notion of creativity is not "just AI search"

Summary

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- Introduced Creative Systems Framework
  - Conceptual Space and Rule Set **R**
  - Traversal of Space to find Concepts and Rule Set **T**
  - Evaluation and Rule Set **E**

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  - Evaluation and Rule Set **E**
- Transformational Creativity is Exploratory Creativity at the meta-level
- The CSF is more expressive than the standard search framework of AI
- We can use the CSF to help conceptualise creative systems