A hypothetical model of spontaneous creativity in improvisation

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Outline

• What I mean by “spontaneous creativity”

• A hypothetical model of cognitive selection that accounts for inspiration
  ‣ Statistical models of cognitive process
  ‣ Information theory

• Extending the model to interactive creativity

• Evaluation – a difficult problem

• Motivation
  ‣ (overall) WHERE DO (MUSICAL) IDEAS COME FROM?
  ‣ (today) HOW DOES (MUSICAL) INTERACTION HAPPEN?
Two kinds of creativity

• One aspect of creativity is **SPONTANEOUS CREATIVITY**
  ‣ ideas appear, spontaneously, in consciousness
  ‣ cf. Mozart (Holmes, 2009, p. 317)
    ◦ When I am, as it were, completely myself, entirely alone, and of good cheer — say traveling in a carriage, or walking after a good meal, or during the night when I cannot sleep; it is on such occasions that my ideas flow best and most abundantly.

• Compare with the composer working to build (e.g.) a new version of a TV theme, on schedule, and with constraints on “acceptable style”
  ‣ this is a different kind of activity: **CREATIVE REASONING**

• Most creative acts of any size are a **mixture of both**

• Here, I focus on **spontaneous creativity** only
EXPECTATION
Expectation allows us to deal with the world
- there is too much data out there to process in real time
- we need to manage it by predicting what comes next, so we have a chance to get ahead

Expectation works in lots of domains
- vision
- movement understanding
- speech understanding
Why should it be so?

- **Key evolutionary points**
  - organisms survive better if they can learn
  - organisms survive better if they can anticipate
  - organisms survive better if they can anticipate from what they learn
  - organisms cannot be merely reactive
    - anticipation must be proactive
  - organisms must regulate cognitive resource – attention is expensive
A uniform account of cognition

• Cognition as information processing
  ‣ To promote survival
  ‣ To manage the world around an organism

• To promote cognition/information processing
  ‣ need memory
  ‣ need compression/optimisation
    ◦ to represent memories as efficiently as possible (reduce cognitive load)
    ◦ to take advantage of any structure/pattern that may be in the perceptual data and avoid repetition
  ‣ need to compare what is perceived with what is remembered, to predict

• A system (biological or computational) that can do these things has a big advantage
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Bernard Baars (1988) proposed the **Global Workspace Theory**

- agents, generating cognitive structures, communicating via a shared workspace
- agnostic as to nature of agent-generators
- information in workspace is available to all agents and to consciousness
- agents gain access to blackboard by “recruiting” support from others
- problem: how to gain access

Avoid Chalmers’ “hard problem”: what is conscious?

- ask instead: what is it conscious of?
• Model expectation in music and language statistically
  - currently using IDyOM model (Pearce, 2005)
    - predicts human melodic expectation ($R^2=.81$; Pearce & Wiggins, 2006)
    - predicts human melodic segmentation ($F_1=.61$; Pearce, Müllensiefen & Wiggins, 2010)
    - predicts language (phoneme) segmentation ($F_1=.67$; Wiggins, 2011)

• Statistical nature means we can apply information theory (Shannon, 1948)
Two versions of Shannon's entropy measure (MacKay, 2003)

- **Information content**: estimated number of bits required to transmit a given symbol as it is received:

  \[ h = -\log_2 p_s \]

  - models **unexpectedness**

- **Entropy**: expected value of the number of bits required to transmit a symbol from a given distribution:

  \[ H = -\sum_i p_i \log_2 p_i \]

  - models **uncertainty**

  - \( p_s, p_i \) are probabilities of symbols; \( i \) ranges over all symbols in the distribution
Instantiating the Global Workspace

- Agent generators
  - statistical samplers predicting next in sequence from shared learned models of perceptual and other domains
  - many agents, working in massive parallel
    - at all times, the likelihood of a given prediction is proportional to the number of generators producing it
  - receive perceptual input from sensory systems
    - continually compare previous predictions with current world state
  - continually predict next world state from current matched predictions
    - sensory input does not enter memory directly
    - the expectation that matches best, or a merger of the two, is recorded
  - consider state $t$ (current) and state $t+1$ (next)
    - at state $t$, we can calculate $h_t$, $H_t$, and $H_{t+1}$ (but not $h_{t+1}$, because it hasn’t happened yet)
Anticipatory agent

Sensory input

uncertainty

Agent$_1$ at $t$

State$_{t-1}$

$h_{t-1}$

Agent$_1$ at $t+1$

State$_t$

$h_t$

Agent$_1$ at $t+1$

State$_{t+1}$

$h_{t+1}$

Distribution$_{1,t}$

match

select

Distribution$_{1,t+1}$

match

select

Distribution$_{1,t+1}$

Distribution$_{1,t}$

match

select

Distribution$_{1,t}$

match

select

State$_{t-1}$

$h_{t-1}$

State$_{t+1}$

$h_{t+1}$

Distribution$_{1,t}$

Distribution$_{1,t+1}$

Sample

record

unexpectedness

Time

Memory
Anticipatory agents in competition

Competitive access to Global Workspace

State t

Agent 1 at t

Agent 2 at t

Distribution 1,t

Distribution 2,t

Sensory input

Memory

Time

Sample

Record

Select

Sample

Select

Select

Select

Select

Select
Anticipatory agents in competition

Competitive access to Global Workspace

State $t+1$ 

$h_{t+1}$

match

$H_{n,1}$

select

Distribution$_1,t$

Agent$_1$ at $t$

Agent$_2$ at $t$

Distribution$_2,t$

$H_{t,2}$

sample

State $t$

$h_t$

select

Sensory input

Memory

Time

record

sample
Selecting agent outputs

- Agents produce (musical) structure representations
- Probability of structure (in learned model) increases “volume”
  - likely structures are generated more often
  - multiple identical predictions are “additive”
- Unexpectedness increases “volume”
  - information content predicts unexpectedness
- Uncertainty decreases “volume”
  - entropy reduces “volume”
Selecting agent outputs

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The story so far

• Mechanism proposed to anticipate and manage events in the world

• Same mechanism can result in creativity in response to sensory input

• Relative lack of sensory input results in “free-wheeling”
  ‣ which in turn allows (apparently) spontaneous creative production
  ‣ cf. Wallas (1926) “aha” moment between incubation and inspiration
    © corresponds with entry of structure into global workspace

• All this is internal to one individual
  ‣ how might cooperative improvisation be included in this framework?
Anticipatory agents in competition

State $t+1$

select

match

Sensory input

$H_{n,1}$

select

Distribution$_{1,t}$

Agent$_1$ at $t$

Competitive access to Global Workspace

$h_{t+1}$

select

State $t$

$h_t$

select

Agent$_2$ at $t$

sustainable input

Distribution$_{2,t}$

$H_{t,2}$

record

Time

sample

Memory

sample

select
Anticipatory agents in cooperation

Player 1

Player 2

Compatible models of music
Shared model of piece
Anticipatory agents in cooperation

Player 1

Player 2

Established entrainment

Compatible models of music

Shared model of piece
Anticipatory agents in cooperation

Player 1

Player 2

State $t$

Select

Distribution $1,t$

Select

Sensory input $H^n,1$

Select

Distribution $1,t$

Select

Competitive access to Global Workspace

Established entrainment

Compatible models of music

Shared model of piece

Play

Play

Agent $1$ at $t$

Sample

Agent $2$ at $t$

Sample

Agent $1$ at $t$

Sample

Agent $2$ at $t$

Sample

Time

Player 1

Player 2
Anticipatory agents in cooperation

Player 1

State $t$

Sensory input $H_{n,1}$

Distribution $1,t$

Select $h_{t+1}$

Sample $H_{t,1}$

Agent 1 at $t$

Competitive access to Global Workspace

Record

Established entrainment

Agent 1

Compatible models of music

Shared model of piece

Play

Player 2

State $t$

Sensory input $H_{n,2}$

Distribution $2,t$

Select $h_{t+1}$

Sample $H_{t,2}$

Agent 2 at $t$

Competitive access to Global Workspace

Record

Established entrainment

Agent 2

Compatible models of music

Shared model of piece

Play

Time
Anticipatory agents in cooperation

Player 1

State $s_t$

Sensory input $H_{n,1}$

Distribution $1_t$

Sample $h_{t+1}$

Agent $A_{1_t}$

Play

Competitive access to Global Workspace

Record

Established entrainment

Compatible models of music

Shared model of piece

Player 2

State $s_t$

Sensory input $H_{n,2}$

Distribution $2_t$

Sample $h_t$

Agent $A_{2_t}$

Play

Competitive access to Global Workspace

Record
Consequences

- **Given**
  - perceptual mechanisms – given as discrete representations – ongoing research
  - learned enculturation – statistical mechanisms
    - musical technique (e.g. ability to hear musically, ability to play)
    - musical knowledge (e.g. chord sequences of particular songs, music “theory”)
  - mechanism for entrainment – open question (Large et al., oscillatory model?)
  - reward mechanism (why is it fun?)
    - maybe somatic responses to memory activity (Biederman & Vessel, 1996)
    - maybe emotional responses to interaction itself (cf. intuitive parentese)
    - these are mechanisms that promote societal bonding = good for survival

- ... improvisatory behaviour naturally arises from a cognitive mechanism for survival in the world
Evaluation

- Creativity is a slippery concept in humans
  - how can we evaluate the model?

- Doing this with music is in a sense easier than with language or other kinds of knowledge
  - no real-world inference necessary
  - but that doesn’t make it easier to evaluate

- **Build the beast and see what it does!**
  - does it produce novel and interesting (musical) ideas?
  - does its behaviour match human behaviours?
  - Use evaluation methods from CC
    - Ritchie’s artefact analysis
    - Colton’s FACE & IDEA formalisms, etc.
Full (long) paper on model due online in next 3 weeks: