Nativism, Empiricism, Representation, and Domain-specificity

Topics in Cognitive Modelling
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John Lee, Chris Lucas
School of Informatics
University of Edinburgh

Goals of this course (1)

Examine the Big Questions of cognitive science through the lens of computational modelling.

- Is cognition a collection of separate domain-specific abilities or an interacting whole?
- How much of cognition is innate?
- Are mental representations symbolic or distributed?
- Are mental processes based on rules or associations?
- To what extent are our cognitive abilities determined by our physical body and environment (i.e., grounded/embodied)?

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Nativism vs. empiricism

Nativism: much of humans' cognitive ability is inborn.

- (cf. Leibniz, Kant, Chomsky, Pinker)

Empiricism: our cognitive abilities are the result of learning from experience.

- (cf. Locke, Hume, Skinner)

We'll discuss modern points of view on both sides, and ideas about representation and domain-specificity that typically go along with these views.

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Behaviourism

- Dominant view in psychology from 1920s-1950s.
  - Only study observable behaviour, not unobservable mental representations, states and processes.
  - All behaviour results from learned associations (stimulus-response).

Image: life.com

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Behaviourism

- Dominant view in psychology from 1920s-1950s.
  - Only study observable behaviour, not unobservable mental representations, states and processes.
  - All behaviour results from learned associations (stimulus-response).
- A highly empiricist view: eschews "human nature", believes social environment is key.

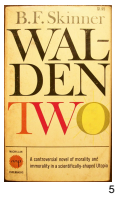

Image: retrobookshop.com

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Problems with behaviourism

- What happens in moments of "insight"?
  - Ex: Chimps figuring out how to get out-of-reach bananas (Kohler, 1927).

Image: Kohler (1927).

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Problems with behaviourism

- What makes humans different from other animals and why do human universals exist across cultures?
  - Partial list of cultural universals compiled by D. E. Brown:*

aesthetics; age statuses, terms; anthropomorphization; baby talk; belief in supernatural/religion; beliefs about death, fortune and misfortune; body adornment; childbirth customs; childhood fear of loud noises; classification of age, body parts, colors, fauna, flora, kin, sex, tools, weather conditions; collective identities; conflict; coyness display; crying; culture/nature distinction; customary greetings; dance; death rituals; diurnality; divination; …

*As quoted in Pinker (2002).

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Problems with behaviourism

- How can learning even happen if nothing exists first?

"Nothing exists in the intellect that was not first in the senses." – Locke*

"Except the intellect itself." – Leibniz*

- The bias-variance dilemma in statistical machine learning is a more formal statement of this problem.

*As quoted in Pinker (2002).

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The cognitive revolution

- Chomsky (1959) attacks Skinner's book Verbal Behavior.
  - Children do not, e.g., utter "house" every time they see one: language use is *stimulus-independent*.
  - Language is infinite; children produce sentences they have never heard, apparently following complex grammatical rules (i.e., internal *knowledge*).
- The start of the "cognitive revolution": the study of the internal mind.
- Additionally, Chomsky argues that much grammatical knowledge is innate.

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Nativism in linguistics

- Chomsky's "argument from the poverty of the stimulus": children's grammatical knowledge is too complex to be learned from the input they receive.
  - Ex. Hierarchical structure vs. linear structure in Y-N questions.

I am going.
Am I going?

The dog is cute.
Is the dog cute?

Hyp: to form Y-N question, move aux. verb to front.

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Hyp: to form Y-N question, move aux. verb to front.

The man who is going is here.

Which aux. verb to move?

Is the man who going is here?
or
Is the man who is going here?

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Nativism in linguistics

Chomsky argues:

- Wrong answer involves linear structure (move the 1st aux).

The man who is going is here.
Is the man who going is here?

- Correct answer involves knowing that sentences have hierarchical structure (move the aux in the main clause).

[[The [man [who [is going]]]] [is here]].

- This type of sentence is not common enough for children to have heard it, yet they do not make errors.*
- Therefore, knowledge of hierarchical structure and relevance of main clause must be innate.

*Both of these points have been disputed more recently.

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Theoretical assumptions

- A set of strong constraints on the possible forms that languages can take (Universal Grammar). UG is
  - Domain specific (e.g., refers to linguistic notions like nouns and verbs, plus much more technical ones)
  - Represented using symbols and deterministic rules.
- An associated learning system (Language Acquisition Device) that works with UG to allow acquisition of particular languages.

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What is in UG? In LAD?

Basic idea: All languages follow certain principles, with certain parameters of variation.

Principle A:
A reflexive pronoun must have a higher antecedent in some domain.

The domain parameter:
Option (a): domain = the smallest clause containing the reflexive pronoun.
Option (b): domain = the sentence containing the reflexive pronoun.

Reflexive pronoun: himself, herself, etc.
Antecedent: the thing the pronoun refers to.

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Principle A:
A reflexive pronoun must have a higher antecedent in some domain.

The domain parameter:
Option (a): domain = the smallest clause containing the reflexive pronoun.
Option (b): domain = the sentence containing the reflexive pronoun.

Parameters are set based on observed input data.

Various specific algorithms have been proposed, often based on "cues" or "triggers", specific types of sentences that indicate specific parameter settings.

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Nativism in other domains

Spelke (1994) presents a nativist view of development in other domains.

Claims that "core knowledge" of physics, psychology, number, and geometry is innate.

- E.g., *Contact principle* for physics: an object can only affect the motion of another object through contact. Domain-specific: does not apply to animals.

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Infant knowledge of physical laws

An experiment:

- If a principle is innate, very young children should be surprised by seeing it violated.
- Looking-time studies:
  1. Habituate (bore) children with one display.
  2. Compare time they look at two new displays:
     a. Violates principle but looks similar.
     b. Obeys principle but superficially different.

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Infant knowledge of physical laws

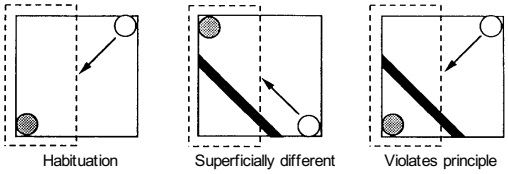

Image: Spelke, 1994

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Infant knowledge of physical laws

Results:

•Infants look longer at violations of continuity than violations of inertia (objects changing paths)

•At the same time, infants reach predictively in accordance with inertia.

Spelke's interpretation:

•Innate knowledge of continuity principle.

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Spelke's nativism:

Similar assumptions to Chomsky:

- Innate knowledge is domain-specific.
  - E.g., law of contact refers only to physics of objects.
- Innate knowledge is about fundamental properties of the world that are not necessarily perceptually salient or even possible to perceive.

Similar arguments to Chomsky:

- Sophisticated early knowledge without much experience indicates innateness: "it just wouldn't be possible to learn X based on the input received."

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Summing up

Strongly nativist researchers assume

- Many basic cognitive functions (perception, reasoning, language, etc.) rely largely on innate knowledge.
- This knowledge is domain-specific, generally using symbolic representations.
- Learning processes are also domain-specific, though many nativists don't actually say much about learning, focusing more on what is *not* learned.
- Sometimes assume strong *modularity*: different parts of the brain are responsible for different functions, and internal workings of modules are opaque to each other.

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Connectionism

- A new incarnation of empiricism, stemming from AI research in the late 70s/early 80s.
  - The beginning of the "statistical revolution" in machine learning, moving from rule-based to statistical algorithms.
  - Artificial neural networks show promise as robust and successful method for learning from data.
  - In machine learning, research on ANNs and their descendants continues as a practical technique.
  - In cognitive science, use of ANNs is typically part of a philosophical view: connectionism.

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Rethinking Innateness (Elman et al., 1996)

- Elman et al.'s "biologically inspired" empiricism:
  - Learning mechanisms and experience are more powerful than nativists believe.
  - Hardware implementation (i.e., neural structure) is critical.
  - Evolutionary origins and environment are also important.

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Image: entwicklungswissenschaft.de

Artificial neural networks

- ANNs reproduce what Elman et al. believe to be the critical aspects of neural structure:
  - Distributed computation using small computational elements.
  - Each element accesses only local information.
  - Information is represented in a distributed way.
  - Responses are nonlinear.

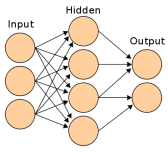

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Figure: http://en.wikipedia.org/wiki/Artificial_neural_network

What is "innate"?

- Elman et al.: "innate" as resulting from organism-internal developmental processes, no external input.
- Three possible kinds of innate constraints:
  - Representational: e.g., principles of grammar or physics are subserved by specialized microcircuitry in the brain.
  - Architectural: e.g., neuron response characteristics, degree of connectivity, connections from inputs to brain regions.
  - Timing: e.g., order of input received, developmental changes in plasticity such as language "critical period".

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What is innate?

- Elman et al. argue against innate representations based on evidence from neuroscience:
  - Transplant fetal tissue from somatosensory to visual cortex: transplanted tissue develops visual processing.
  - Rewire input signals to different brain regions: functions will change.
- But happy with innate architectural and timing constraints: humans are not a completely blank slate.

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Constraints in ANNs

- Representational: would mean fixing some weights between nodes rather than learning them.
- Architectural: number of nodes and layers, connections, feedforward vs. recurrent, etc.
- Timing: stimulus presentation order, changes in learning rate parameters, etc.

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Domain-specificity

- Connectionist view on domain-specificity:
  - Domain-specific representations are learned.
  - Domain-specific processing is learned.
  - Neurological arguments seem to rule out domain-specific architectural constraints, but in practice models tend to have these.

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Summing up

Most connectionist researchers assume

- The brain contains powerful general-purpose learning mechanisms, so innate domain-specific representations and learning mechanisms are unnecessary.
- Representations and processing are inherently distributed and statistical.
- Constraints on learning result from neural architecture and timing (though many connectionists don't talk much about constraints; leading to misunderstandings that they claim there are none).
- Modularity is unlikely due to distributed representations and processing.

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Conclusion

Almost no researchers believe humans are a completely blank slate, arguments are about extent and nature of innate constraints.

- Modern nativists:
  - Innate knowledge includes extensive domain-specific representations and processes.
- Connectionists:
  - Innate constraints arise from physical architecture and are not domain-specific.
  - Representation and processing are distributed and also not domain-specific.

Next time: Artificial neural networks, bias-variance trade-off

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Reminders

Browse the topics on the reading list; A survey will be circulated to pick topics and assign groups.

The readings themselves are password protected:

U: t.....

P: 2.....

(For those not in class, this will be emailed)

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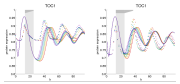

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