19th Century Roots of Behavioral Neuroscience

Review: D-N and Kuhn

The received view of scientific explanations made laws central

- Laws (Newton’s force law: \( f = ma \))
- Initial conditions (object of a given mass is acted upon by a specific force)
- Phenomenon to be explained (object will experience a specific acceleration)

Science advances by proposing and testing hypotheses, generally in a cumulative fashion

- Reduction involves deriving the laws of one science from those of a more fundamental science
- Kuhn—science often progresses through revolutions that replace one “paradigm” with another

Normal science consists of trying to force a paradigm onto nature, not testing hypotheses

Biology and Mechanistic Explanation

Despite the received view’s focus on laws, biologists (including neuroscientists) seldom appeal to laws (except laws of chemistry and physics, as appropriate)

- Apparent counter example: Mendel’s laws of dominance, segregation, and independent assortment

  None of which are true (there are exceptions to each)
  What Mendel did offer was a sketch of a mechanism of inheritance

- He postulated factors, a process through which they were inherited, and an account of how they related to traits
- He had no evidence for the mechanism other than that it gave the right answers to inheritance patterns in peas
- But in the 20th century Mendel’s factors were named genes, their location on chromosomes established, their composition out of DNA was determined, and the mechanism by which they are expressed in proteins discovered
Characterizations of Mechanisms

Machamer, Darden, and Craver (MDC) (2000)
“Mechanisms are entities and activities organized such that they are productive of regular changes from start or set-up to finish or termination conditions”

“A mechanism is a structure performing a function in virtue of its component parts, component operations, and their organization. The orchestrated functioning of the mechanism is responsible for one or more phenomena”

Besides the incidental differences in vocabulary, the major difference involves the last phrase of MDC—imposing an order from start to termination conditions

Clicker Question

Which of the following represents a way in which mechanistic explanations are different from D-N explanations

A. They don’t explicitly refer to laws
B. They attempt to account for why events happen
C. They can be presented in language
D. They must be tested

Mechanistic Versus Nomological Explanations

Both nomological and mechanistic explanations can be concerned with causal phenomena—something happens which brings about something else

Nomological explanations focus on the regularity (law) characterizing the change itself and does not specifically identify causes
And don't respect temporal order (you can explain what was true in the past given what is true today and laws)

Critical feature of mechanistic accounts is that they focus on the system in which change is occurring and ask what is going on inside to produce its behavior—specific causes

Laws are not central to mechanistic accounts (they may be invoked to characterize operations, but they need not be)

Mechanistic explanations are not presented as logical arguments
Whereas in D-N explanations logic is the “glue” that links laws and initial conditions to phenomena being explained, in mechanistic explanations scientists model (mentally, physically, or computationally) how the parts and operations produce the phenomenon
Descartes: The Origins of the Mechanical Philosophy

“I have described this earth and indeed the whole universe as if it were a machine: I have considered only the various shapes and movements of its parts” (Principia IV 188).

All action in the physical universe due to shape and motion bits of physical matter that push and pull against each other

- No vacuum
- No action at a distance
- Nerve transmission and brain activity purely mechanical (albeit influenced by the mind in humans)

Descartes: Human Bodies are Machines

For Descartes, any behaviors we share with animals are the products of mechanisms

- Perception
- Memory
- Emotion
- Action

“... the reception of light, sounds, odors, tastes, warmth, and other like qualities into the exterior organs of sensation; the impression of the corresponding ideas upon a common sensorium and on the imagination; the retention or imprint of these ideas in the Memory; the internal movements of the Appetites and Passions; and finally, the external motions of all the members of the body ... I wish that you would consider all of these as following altogether naturally in this Machine from the disposition of its organs alone, neither more nor less than do the movements of a clock or other automation from that of its counterweight and wheels ....”

Descartes: Mind-Body Dualism

But Descartes could not conceive how thought or language could be generated mechanically

- We have an unlimited capacity for generating new sentences and new thoughts
- Which are appropriate to their context

Res cogitans: thinking thing
- Which affects the physical body at the pineal gland
Connecting Cognition to the Brain

A first step in relating two things is to find some correlation between them.
- Identify some components of thinking.
- Correlate them with some components of the brain.

Observationally, the brain seems inert.
One ultimately misleading clue: its convoluted structure of sulci and gyri—these might be parts that individually are responsible for different mental activities.

Franz Gall and Phrenology

Around 1800 Gall proposed a way to correlate mind and brain.
- Divide the mind into mental faculties.
  - Capabilities that some people are better and some are worse at.
- Identify differences in people’s skulls.
  - Attribute bumps on the skull to increased growth in the underlying brain area.
- Relying especially on individuals with especially developed mental traits (good or bad), correlate faculties with bumps on their skulls.

Clicker Questions

What role do animals play in Gall’s discussion of faculties?
- He performed experiments on their brains to identify what happened when parts were removed.
- He treated different species as exhibiting high levels of different faculties that corresponded to the parts of their brains.
- They are never mentioned since he thought mental activity occurred only in humans.
- Other
Faculties and Brain Regions

Different species of animals have different behavioral propensities
Different people show greater development in specific propensities (some are better at arithmetic, some faster to anger, etc.)
Propensities are due to different regions of the brain
Propensities would be stronger when the responsible brain region is larger
Propensities would be lost when the corresponding brain region is absent or damaged

The Popularity of Phrenology

Phrenology became very popular with the public—people would pay to have their skull read
Against Phrenology: Pierre Flourens

“The entire doctrine of Gall is contained in two fundamental propositions, of which the first is, that understanding resides exclusively in the brain, and the second, that each particular faculty of the understanding is provided in the brain with an organ proper to itself. Now, of these two propositions, there is certainly nothing new in the first one, and perhaps nothing true in the second one.”

Flourens

Four Functionally Separate Parts of the Brain
- Cerebellum: regulates locomotion
- Tubercula quadrigemina (inferior and superior colliculus): involved in vision
- Medulla oblongata (part of the brain stem): involved in respiration
- Brain proper (cerebral hemispheres or neocortex): “the exclusive seat of intelligence”

Flourens conducted experiments on pigeons and rabbits
- He removed (lesioned parts of their brain proper (cerebral cortex) and examined the effects on behavior

Clicker Question

What did Flourens discover from his lesion studies with animals
- Specific lesions produced specific deficits in their intelligence
- Some animals seemed to be more intelligent as a result of lesions
- Lesions had absolutely no effect on the intelligence of the animals
- The more tissue Flourens lesioned, the greater the loss of intelligence
No Divisions in the Hemispheres

No lesion results in a specific loss of intelligence.

“As has been shown by my late experiments, that we may cut away, either in front) or behind, or above, or on one side, a very considerable slice of the hemisphere of the brain, without destroying the intelligence. Hence it appears, that quite a restricted portion of the hemispheres may suffice for the purposes of intellect in an animal.

But overall intelligence is reduced proportional to the amount removed.

“On the other hand, in proportion as these reductions by slicing away the hemispheres are continued, the intelligence becomes enfeebled, and grows gradually less; and certain limits being passed, is wholly extinguished. Hence it appears, that the cerebral hemispheres concur, by their whole mass, in the foil and entire exercise of the intelligence! As soon as one sensation is lost, all sensation is lost; when one faculty disappears, all the faculties disappear. There are not, therefore, different seats for the different faculties, nor for the different sensations.”

Phrenology Falls into Disrepute

Despite its popularity with the general public, the scientific community rejected phrenology.

This put a damper on any attempts to localize mental activities in the neocortex.

Those who did embrace any claim to localize functions in the cortex were labeled neophrenologists.

Clicker Question

What was the language deficit that Broca identified in his patient Leborgne (Tan)?

A. All language abilities were lost
B. Tan could not produce any vocal sounds
C. Tan could not produce articulate words
D. Tan could neither produce words nor understand those spoken to him.
Aphemia: Loss of Articulate Speech

Broca begins by identifying a specific kind of loss of intellectual capacity: the loss of the ability to produce articulate speech.

- Not the loss of all language: could still understand language
- Not the loss of general intelligence: could still perform tasks requiring intelligence
- Cannot fully resolve whether this is a loss of learned coordination of motor activity or of a higher cognitive capacity

Leborgne (Tan)

Became Broca’s patient only when already close to death at the age of 50
- Had experienced epilepsy from youth and lost the capacity for articulate speech at about 30
- No loss of understanding or of intelligence
- Around 40 began to lose the capacity for movement
- Died soon after coming under Broca’s care and, upon death, Broca performed an autopsy
- Massive amount of damage
  - Broca argued that the damage was centered on the third frontal convolution and that is where it originated

Discussion Question

You open the hood of your car, remove something, and your car will no longer drive in reverse. You conclude that you have removed the reverse engine. How could you be wrong?

- There is a possibility that the part you removed only connects the reverse engine to the wheels
- The car may not have a reverse engine—it has only one engine whose torque is applied either in moving forward or backwards
- You might have removed the controls that activate the reverse engine, which is still perfectly functional
- All of the above
Uongoing Challenge

There is no question that the damage to the region Broca identified (there is some question as to where precisely it is located) results in language deficits. But what exactly do the deficits consist in and what does the region do?

Broca—center for articulate speech
1970s—center for syntactic processing
in recognition that Broca’s patients do experience some comprehension deficits
And other proposals

From Localization to “Connectionism”

Model for mimicking speech
(a) Center for “acoustic images”
(b) Center for “motor speech images”

Connection between them
damage results in conduction aphasia
To account for reading and writing, one might add centers for visual letter imagery and graphic motor imagery
All the rest due to connections: “Any higher psychic process, exceeding these mere primary assumptions, could not, I reasoned, be localized, but rested on the mutual interaction of these fundamental psychic elements mediated by means of their manifold connections via the association fibers.”

Classification of Aphasias

Adds a concept center B
Identifies 7 different possible aphasias (likewise alexias and agraphias)

Cortical sensory aphasia
Subcortical sensory aphasia
Transcortical sensory aphasia
Cortical motor aphasia
Subcortical motor aphasia
Transcortical sensory aphasia
Conduction aphasia

Empirical question: do all of these occur?