Crossroads of economics and cognitive science.

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Summer, 2002

Outline

1. A map of the two “fields” (terminology and methods)

2. Some economic questions raised by neuroscience.
   - brainstorm
   - make connections
   - stimulate discussion
   - speculate (no extended warranties)

3. Identify a general modeling framework

Economics in Nutshell

- Preferences (utility function): $u(c_1)+ßu(c_2)$.
- Knowledge (beliefs):
  stock market has expected return, r, of 8%
- Constraints: $c_2=(1+r)(Wealth-c_1)+y_2$.
- Maximization:

$$\max_{c_1} E\,[u(c_1)+ßu(c_2)]$$

  subject to the constraint

$$c_2=(1+r)(Wealth-c_1)+ y_2$$

Economic modelling

- universal framework:
  one basic model used by all economists

- generalizability:
  one model for all situations

- Parsimony

- ‘as if’ modeling:
  emphasizes evaluation of predictions

- policy science

Cognitive Science in Nutshell

No single framework exists

Many complementary and overlapping frameworks

Rough survey of the cognitive science *fields*:

- Psychology (esp. cognitive psychology): how do people process and react to stimuli/information?

- Cognitive neuroscience: measuring and modeling brains

- Computational intelligence (‘artificial intelligence’):
  1. intelligent machines
  2. computational modeling of human intelligence

- Linguistics: study of language

Each of these fields is less parsimonious than economics.

E.g., psychology has no organizing principle or model

Taken together, the cognitive sciences are spectacularly heterogeneous (relative to economics)

Terminology:

- Neocortex: rational (new mammalian) brain.
- Limbic system (Amygdala, Hippocampus, Hypothalamus…): emotional brain.
- Primitive (reptilian) brain: instincts, autonomic nervous system, basic survival.
- Neuron: brain cell.
- Synapse: juncture between neurons.
- Neurotransmitters (e.g., Dopamine --- DA --- and Serotonin).

More terminology:

- Gene: a segment of DNA that is used to manufacture a protein (e.g., LEP encodes the Leptin protein; DRD4 encodes the D4 dopamine receptor)
- Gene Polymorphism (aka Allele): a variant of a gene (e.g., a LEP allele is associated with obesity; a DRD4 allele is associated with ADHD).
- Molecular genetics: genotyping.
- Behavioral genetics: twins studies.

More terminology

- Homeostasis: stabilizing mechanisms that prevent our physiological systems from getting far away from equilibrium (blood flow to cheeks on a cold day).
- Conditioned responses: cue-based anticipatory responses to a physiological stimulus (e.g., salivation upon presentation of food cues)
- Compensatory conditioned response: conditioned responses that are homeo-static in nature (e.g., preparatory responses to drug ingestion)

Methods

- Animal behavioral studies (e.g., addicting rats to cocaine)
- Studies of autists and children (Sally et al 2001).
- External physiological measurement (e.g., pupil dilation, voice tone, facial expression, skin conductance, heart rate)

More methods...

Studies of brain lesions or localized damage...

- e.g., experimental destruction of both amygdalas in an animal tames the animal, making it sexually inactive and indifferent to danger like snakes or other aggressive members of its own species
- e.g., humans with lesions of the amygdala lose affective meaning
- e.g., hippocampus removal prevents experiences from being encoded in long-term memory

More methods

- EEG, PET, fMRI… (taking pictures of the *active* brain; e.g., McCabe, Houser, Ryan, Smith, and Trouard 2001).
- Neuron measurement (e.g., track high frequency dopamine release in animal models, Schultz et al)
- Brain stimulation (e.g., electrical stimulation of the amygdala elicits violence and aggressivity; at special loci, electrical brian stimulation is highly reinforcing)

McCabe et al (2001)

- Subjects play cooperation games against human subjects and computers.
- Subjects who attempt cooperation show greater prefrontal cortex activation when they play humans than when they play computers.
- Subjects who do not attempt cooperation show no differential activation.

More methods

- Gene studies (using animal models, researchers can manipulate specific genes; using humans, researchers can study behavior in populations with specific genes like APOE)
- Computational brain models (e.g., neural nets)

Some economic questions raised by cognitive science.

Preferences

Knowledge

Constraints

Maximization

Preferences:

- Why do preferences vary across individuals?

1. Experiential (especially in early life)
   - ‘motherless’ monkeys, infant rats handled by humans (Ferris)
   - songbird brains affected by exposure to specie-specific songs
   - chronic drug use

2. Genetic

- family, twin and adoption studies support genetic component in drug abuse vulnerability and ongoing drug dependence (Gardner)
- most phenotypes show 50% heritability
- breeding for behavioral dispositions
- Lewis rat strain exhibits polydrug preference (e.g., ethanol, nicotine, opiates, cocaine); related to dysfunction in DA regulation in DA forebrain reward system (Gardner)
- (same DA dysfunction can be induced by chronic drug use)
- violence: suicide, delinquent anti-social and criminal behavior (Coccaro); low serotonin?

- How do preferences change over time (intra-personal variation)?

1. Long-run variations: drug use ?
    (a) decreased DA synthesis
    (b) depletion of extracellular DA
    (c) withdrawal and tolerance; u(c-x)
2. Short-run variations
    (a) cue-based cravings (Siegel; Laibson)
    (b) cue-contingent tolerance (Siegel)
    (c) conditioned responses (Pavlov)
    (d) ‘visceral’ responses (Loewenstein)
    (e) expectancy-based cravings (Schultz)
3. lifecycle variation
    (a) age declines in BSR and DA (Gardner)

- Are preferences and constraints separable?

  Cues, choice sets, expectancies increase appetites (Siegel; Laibson; Gul and Pesendorfer)

- What are the carriers of utility?

  symbols ($$$)
  cues
  expectancies

  } DA (excitatory or inhibitory)

(Berridge, Schultz, Gardner, Shizgal)

- What links preferences across behavioral domains?
  - Gene based research and neurochemical pathways research.
    * eating disorders
    * gambling
    * obsessive-compulsive disorder
    * impulse shopping
    * drug consumption
    * procrastination
  - e.g., reward deficiency syndrome? D2 allele? Blum
  - other more successful gene or multi-gene syndromes?
  - serotonin?

- Can we measure preferences without revealed preference?
  - left/right brain asymmetry (Kahneman)
  - real time mood measures
  - extracellular DA?
  - genotypes
- How well do we know our own preferences?
  - peak-end effects (Kahneman)
  - decision utility vs. experienced utility (Kahneman)
  - affect system
  - dual process models (inaccessible emotional motives)
- How can we change preferences?
  - Prozac?
  - Cognitive behavioral therapies.

Knowledge

- How does knowledge evolve (learning)?
  - neural networks
  - reinforcement learning (Sutton and Barto)
- How do we store/encode information (memory)?
  - working (RAM; probably cortical)
  - declarative (Matthew's last name)
    hippocampus lays down these memories
  - procedural (how to catch a baseball)
- How does knowledge decay?
- How is knowledge acquired?
  - information automatically filtered before perception
  - change blindness

  (O'Regan http://nivea.psycho.univ-paris5.fr/)

- What role does attention play?
  - "red" neurons don't fire when animal is required to attend to green objects (Desimone)

- Do decision-makers understand the fallibility of their own knowledge (metaknowledge)?
  - Why do I dislike this food, person, or place?
  - Why did I open this door?
  - Will I remember where I am putting my keys?
  - Inaccessible affective motives (sense-making)

- How well do decision-makers understand their internal neurochemical world?
  - conditioning, homeostasis, opponent processes
  - information filters
  - memory mechanisms

Constraints

- For an economist interesting constraints are all external (e.g., choice sets, prices, time, wealth,…)

- But, cognitive science may offer a new set of "constraints" that will mediate maximization
  - costs of thinking (Payne, Bettman, Johnson; Baumeister; Gabaix, Laibson, Moloche, and Weinberg)
  - perception and recall delays
  - dual process cognition

- And new tools to measure cognition processes
  - EEG, PET, fMRI (learning application)
  - visors for measuring visual focus
  - mouselab

Dual process cognition

Emotional system

- limbic
- fast
- parallel
- affective
- unconscious
- experiential
- associationist
- connectionist
- analogical

Analytic system

- cortical
- slow
- serial
- logical
- conscious
- hypothetical
- creative
- forward-looking
- abstract

Maximization: How do people actually make decisions?

- What information is used?
  - emotional responses based on irrelevant cues (Damasio, LeDoux)
  - affect heuristic (Slovic)

- Who is in control?
  - Neo-cortex?
  - Affective (limbic) system?
  - Does the neo-cortex sometimes leave the brain on emotional auto-pilot?

- What mental modules do we use for different types of problems? (Neo-cortex, amygdala, etc...)
- What decision-making skills are inheritable? (e.g., abstract reasoning)
- Do specific genes regulate decision-making? Serotonin? APOE?
- How much decision-making can be modeled as reinforcement learning? (Camerer, Roth, Sutton and Barto)

- More semi-autonomous players?
  - amygdala (LeDoux)
  - visceral responses (Loewenstein)
  - hypothalmus feedback loops (panic attacks?)
  - unconscious (Berridge, Shizgal)

A general framework for "Neuro-Economics"

- External world (prices, endowments)
- Homo Economicus (conscious, maximizing agent, neocortex or pre-frontal cortex?)
- Neurochemical world (production function for cognition and reward, limbic system, DA system)

(A richer neuro-behavioral alternative to the standard model, but still a reductionist ‘as if' model.)

Homo Economicus (maximizing agent)

- picks “actions” (including turning on the emotional autopilot; and trying to suppress it when it gets out of control)
- some actions affect external world (buy gas for my car)
- some actions affect internal world (direct attention or rehearse a memory)
- some actions affect both (buy cocaine, which is appetite arousing)

Neurochemical world (production function for cognition and reward)

Technologies for...

- perception, attention
- memory
- computation
- intuition (gut instincts; affect)
- non-conscious action (e.g., circulation or LeDoux's fear reflexes)
- reward, affect

Homo Economicus tries to increase rewards (which are produced by neurochemical world), taking into account constraints implied by external world and neurochemical world.

Economists may wish to think of this as a maximization problem.

The maximization is subject to both external constraints (e.g., budget constraints) and internal constraints:

- limited perception
- limited memory
- limited attention
- limited calculation ability
- limited appetite (i.e., reward potential)
- limited self-knowledge
- limited self-control (it takes effort to control the limbic system; Baumeister)

Authors who have written papers that belong in this class:

- Loewenstein (visceral effects)
- Kahneman (imperfect memory)
- Laibson (conditioned cue-initiated appetites)
- Romer (conditioned appetites)
- Mullainathan (imperfect memory)
- Gul and Pesendorfer (choice based appetites)
- Benabou and Tirole (memory technologies)
- Bernheim and Rangel (conditioned visceral effects)
- Camerer and Loewenstein (JEP overview)