A lazy brain?
Embodied embedded cognition and cognitive neuroscience

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Questions

- There appears to be a ‘slight tension’ between EEC and (cognitive) neuroscience
- Whence ‘the opposition’?
  - The brain not as a conductor (Chiel & Beer, 1997) but rather a player in a jazz ensemble
    - More attention (funding) for body & environment = less for the brain?
    - Implying that the brain is not ‘really’ important or just lazily comping along?
- Can there be such a thing as

  Embodied Embedded Cognitive Neuroscience?

Contents

- Traditional cognitive neuroscience
  - Modularity, flowcharts & dissociation
  - Weakly EECy: the embodiment of meaning
- Really EECy
  - Alternative view on the primary tasks of the brain
    - Common sense behavior, autopilot & deep thought
    - Temporary behavioral repertoires & traffic regulation
  - Embodied Embedded Cognitive Neuroscience
    - Experimental setups
    - Brain measurements

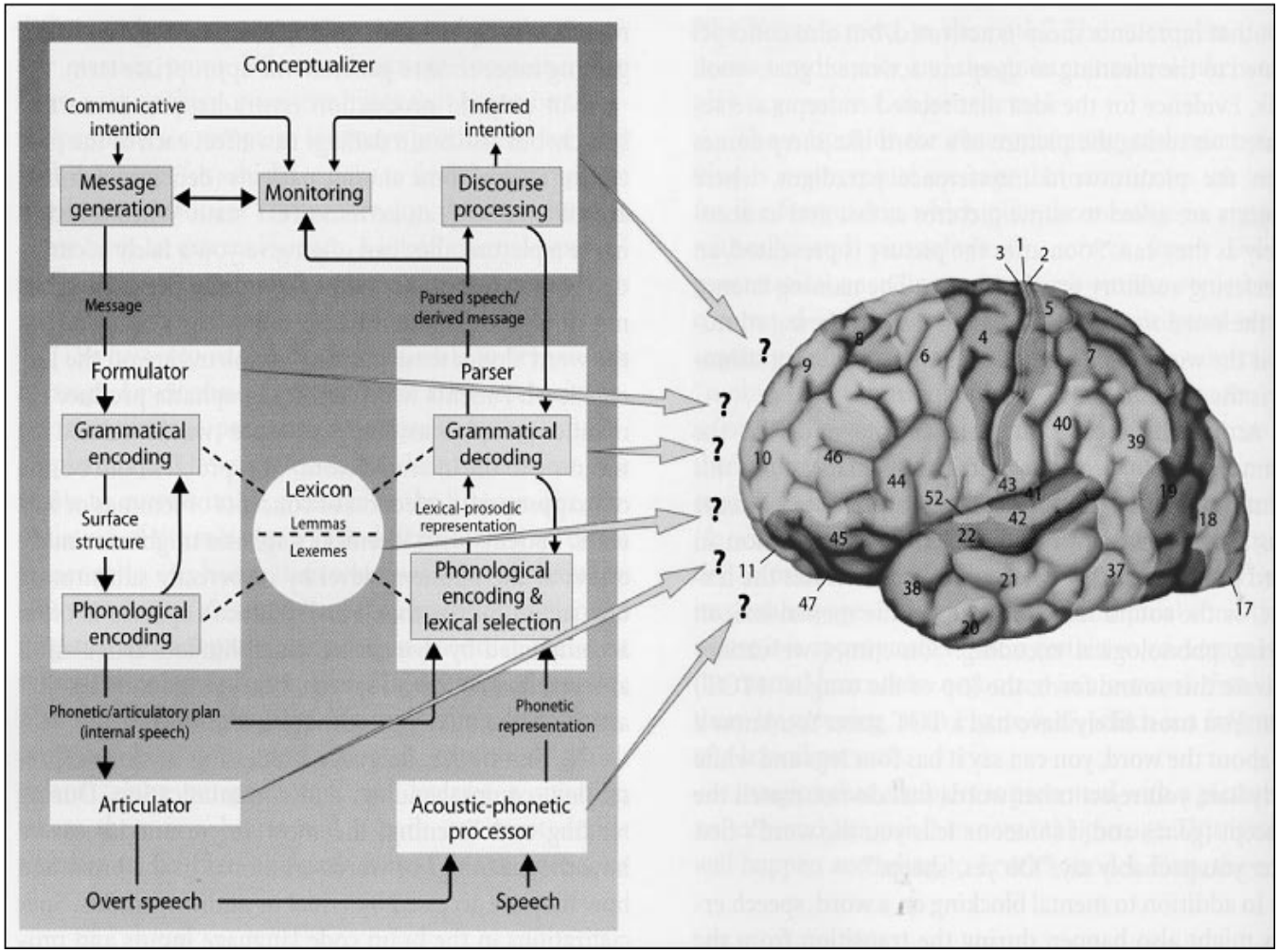
Functional analysis

- Levels of analysis
  - Task (what)
  - Functional (how)
  - Physical (where)
- Functional decomposition and localization (Bechtel & Richardson, 1993)
  - Decomposition:

    the task performed by the system is decomposed into sub-functions (information processing operations)
  - Localization:

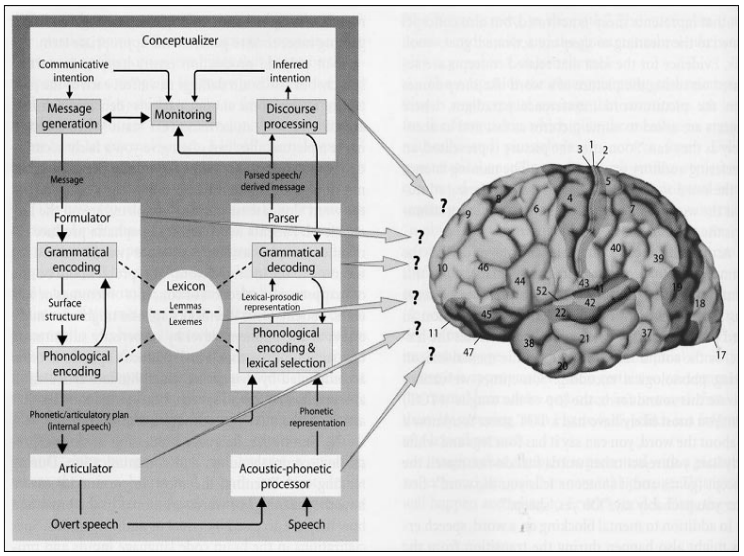
    the physical parts of the system that perform the sub-functions are identified

Modules, flowcharts & the brain

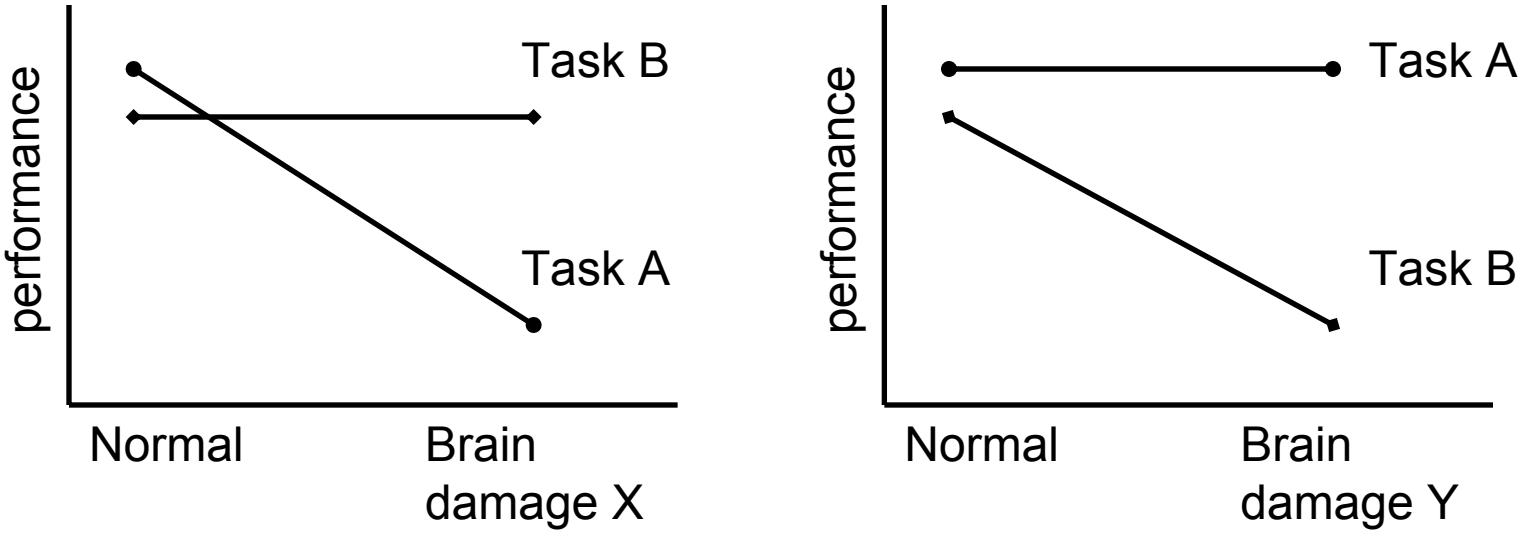


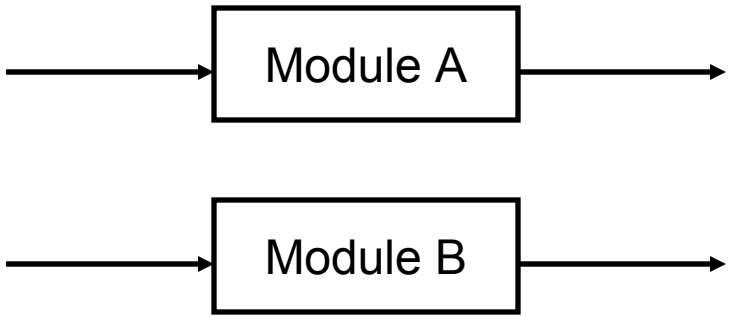
Control rooms

- Central executive board box
  - Where everything comes together
    - Endproducts (representations) of all intermediate information processing stages
  - Models situation, plans, reasons, decides
  - Sends directives to the lower echelons



Double Dissociation





Double Dissociations: Examples

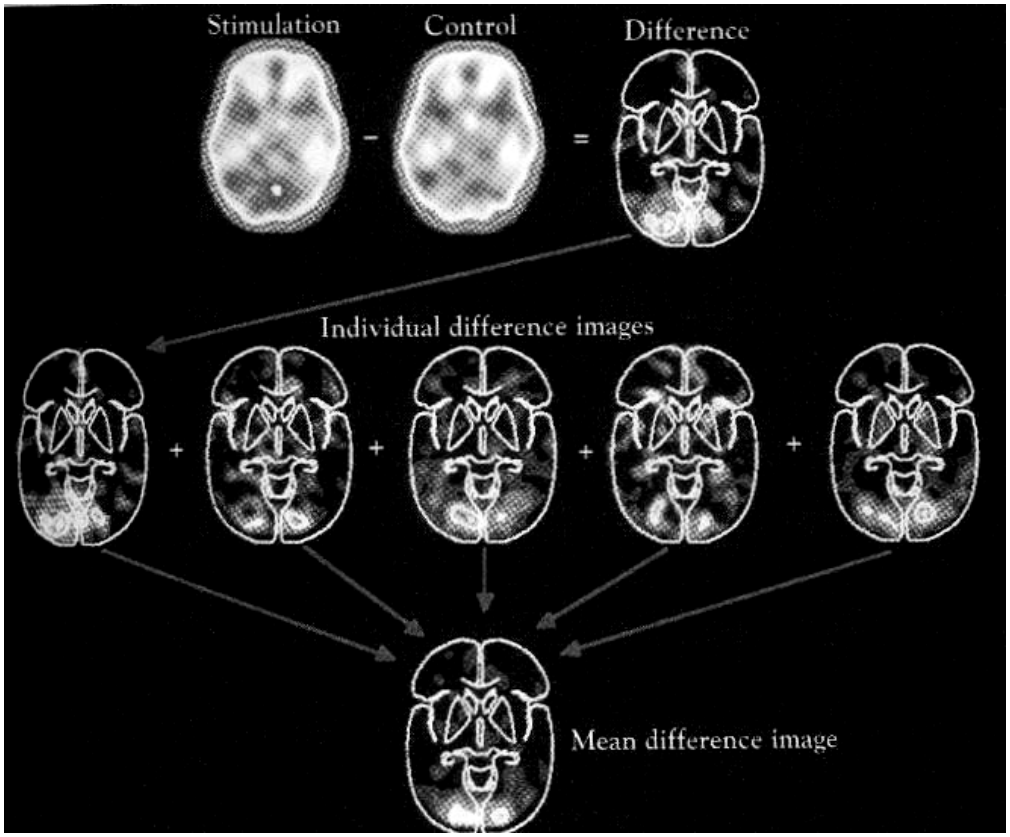
- Amnesics have abnormal explicit memory, but normal implicit memory (Graf et al. 1984, Vaidya et al., 1995). The reverse for patient MS (Gabrieli et al., 1995).

  Inference: Explicit and implicit memory are realised by independent brain modules.

- Zooagnosic farmer MX lost ability to recognize cows, while still able to recognize faces (Assal, Faure & Anderes,1984). The reverse condition applied for patient RB (Bruyer et al.,1983).

  Inference: Perception of faces and non-face objects is realised by independent brain modules.

The subtraction method



Brain areas that show a significantly more activation for the target task than the control subtask are inferred to be the neural correlates of (parts of) the module(s) that are necessary for performing the additional component in the target task

Weakly EECy: Language

- Cognitivism
  - Abstract and amodal representations
  - Sensory and motor information is relatively unimportant for meaning
- Embodied framework
  - Modal representations
  - Sensory and motor information play crucial role in meaning

Wiemer-Hastings et al.

- Cells selectively sensitive to vertical lines or horizontal lines are habituated
- Reaction times on words are measured
- The words come in two categories:
  - Vertical words: e.g., TOWER
  - Horizontal words: e.g., TRAIN

Wiemer-Hastings et al.

- Results:
  - Words like TOWER were responded to slower
    - when participants were habituated to vertical lines
    - than when they were habituated to horizontal lines.
  - Words like TRAIN were responded to slower
    - when participants were habituated to horizontal lines
    - than when they were habituated to vertical lines

Wiemer-Hastings et al. II

- Cells selectively sensitive to colors are habituated
- Reaction times on words are measured
- The words come in two categories:
  - "red" words: e.g., TOMATO
  - "blue" words: e.g., GRAPE
- TOMATO is slower
  - when participants were habituated to red compared to
  - when participants were habituated to blue and vice versa
- Conclusion
  - Primary visual areas are part of the representation of the meaning of nouns

Intermediate conclusions

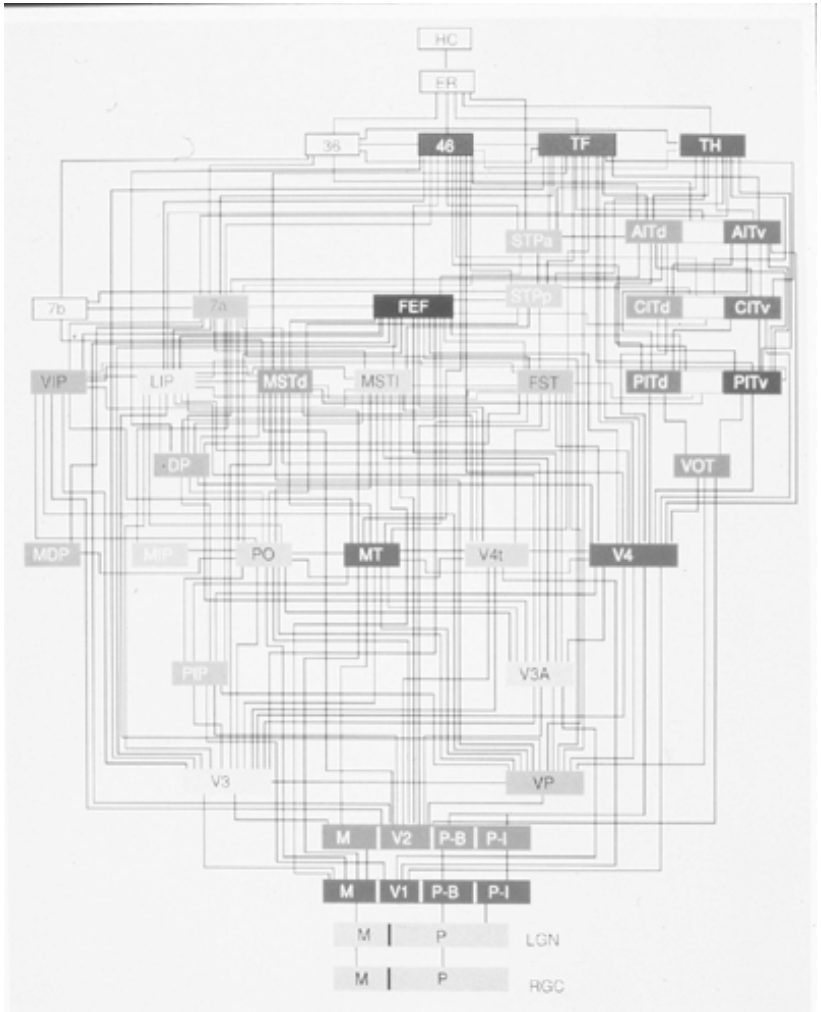
- Sensory and motor information play an essential role in language comprehension
  - Wiemer-Hastings et al.: Early visual cortex is involved in the representation of the meaning of nouns
  - Pulvermüller et al.: Motor cortex is involved in the representation of the meaning of action verbs
  - "This view of meaning is embodied in that meaning depends on an individual having had experiences in their body in the actual world, where they recreate those experiences in response to linguistic input, and use them to produce meaningful linguistic output" (Bergen, in press).
- The designs of the experiments remain within the confines of the traditional view & laboratory set-up
  - 'Unexpected' modules participate in meaning

Does dissociation lead to modules?

- Double dissociations do not prove the existence of two independent modules.
  - The inference is abductive, not deductive.
  - Coltheart (2003) argues that this is how empirical inference should be
  - But alternative (non-modular) explanations are possible (Shallice, 1988)
- Search for dissociations may have detrimental consequences
  - Puts a ‘straightjacket’ on tasks
  - No two tasks recruit exactly the same mental processes, so dissociations are to be expected in general
  - Double dissociation methodology could lead to an unending fractionation of the mind into more and more (and smaller and smaller) modules

Decomposition?

- "Decomposition assumes that one activity of a whole system is the product of a set of subordinate functions performed in the system.
  - It assumes that there are but a small number of such functions that together result in the behavior we are studying,
  - and that they are minimally interactive (...) additively or perhaps linearly."
    - Bechtel & Richardson (1993, p.23).

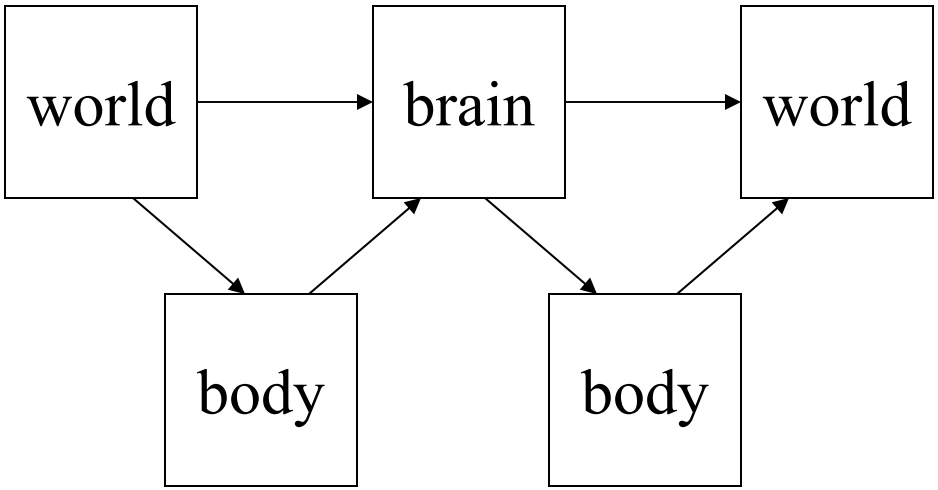


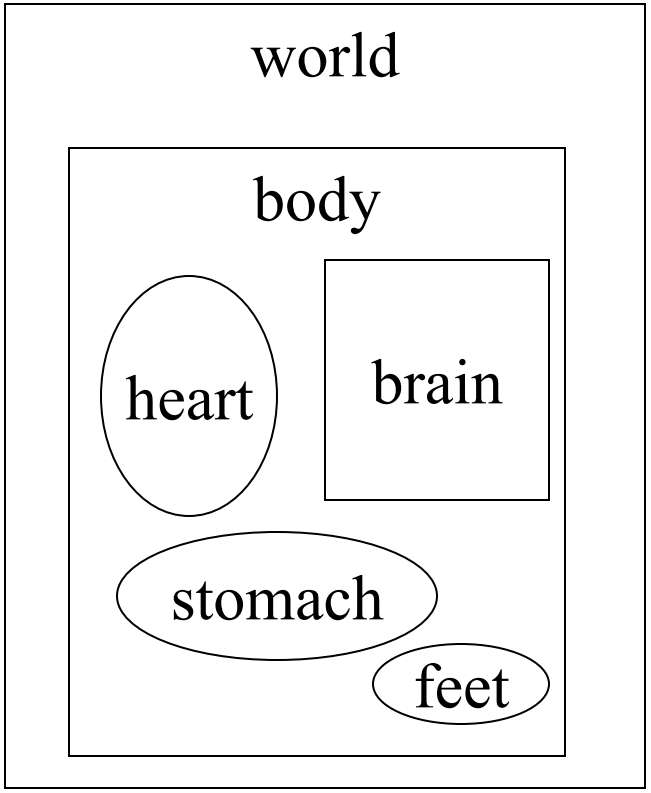
Felleman & van Essen (1991)

Most of the links are reciprocal

Really EECy

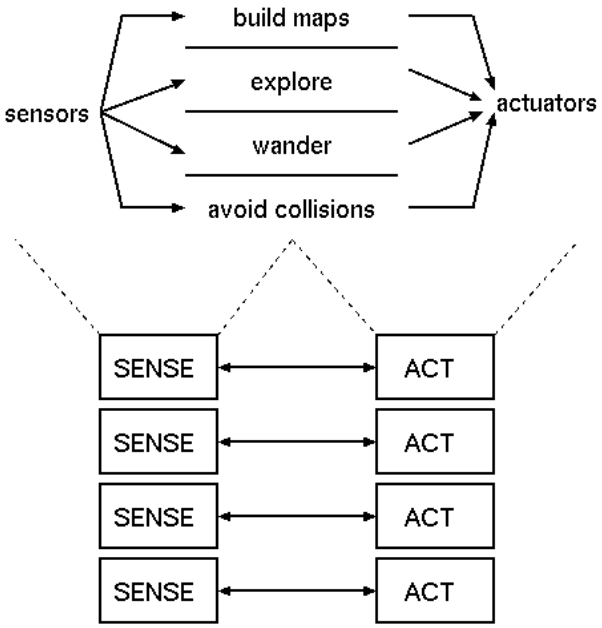
The dynamic coupling between world, brain and body





Behavior before the brain

- E. coli, a single-cell organism without nucleus (prokaryote)
- Moving its flagella in two ways
  - change from tumbling about randomly to swimming in one direction.
- Without specific stimulation
  - it changes between these two modes every few seconds.
- Chemical gradient changes in its environment
  - increase the amount of swimming



Reactive Robots & Dynamic Agents

- RR: A reactive creature consists of behavioral layers that each instantiate input-output couplings

- No high-level world modeling, planning and decision making takes place
  - DA: Internal states are allowed & necessary
- The layers themselves compete for dominance on the basis of the input received by the system
- A creature is a moving repertoire of (complex, internal state-based) behavioral dispositions out of which the environment selects

Increasing complexity

- Of the creature
  - Capacity to receive input, perform actions
  - Structure (morphology)
- Of the environment
  - The variety of environments it can subsist in
  - The challenges it can confront within an environment
- Need for integration & coordination
  - The brain
    - peripheral (e.g. enteric nervous system)
    - central

Reinterpreting the brain's main task

- EEC implies a different conceptualization of the primary task of the brain
- Not:

  focused on problem solving by means of integrated internal information processing, model building, planning and decision making ("Control room-ism")
- But:

  contributing to the ongoing interaction with the environment in a, when possible, basic perception-action cycle based way

Auto-pilot & deep thought

- Many times we function on auto-pilot
  - Almost automatically, habitual, on-line
- Other times we operate on the basis of ‘deep thought’
  - Concentrated, conscious, off-line
- The majority of our daily life activities (‘getting by’) is based on the automatic pilot mode
  - Stop & think, switch to deep thought, quickly return to auto-pilot
  - Various kinds of ‘laziness principles’ sustain auto-pilot

The laziness principles

Cognitive strategies for being lazy instead of tired

- Let the environment do the difficult work for you
  - scaffolding
- Don't think: Act!
  - just get started
    - the environment can correct you
    - it's often possible to adjust later on
- Copying and imitating are good
  - follow 'mam and dad'
- Postpone
  - don't think now of what you can think about later

    (something may happen in the meantime)
- Lower your ambitions
  - if the world doesn't cooperate: "Oh well, it's not all that important anyway"
- Seek company of people that agree with you
  - Call them 'friends'

The brain as a traffic facilitator

- Primary task of the brain
  - Facilitate the ongoing display of behavior in the light of the body's needs and its history of world interaction
- Temporarily 'loading the dice'
  1. constitute (complex, internal state based) potential behaviors
  2. provide precedence relations between them
- Becoming a different behavioral system 'on the spot'
  - and let the environment select from the repertoire

Traffic (regulation) options

- Blocking potential behaviors
  - that would otherwise (i.e. due to the basic interaction cycle) have emerged
  - letting the environment re-stimulate the behavioral repertoire and thereby re-selecting a more appropriate behavior
- Maintaining behaviors that would otherwise have died out
  - by delaying other behaviors, or by generating positive or suppressing negative emotions
- Enhancing behaviors
  - for example speeding up the start of a behavioral sequence
- Favoring actions for the effect they will have on the brain's traffic regulation function
  - epistemic action
- Creating different or new behaviors
  - thinking

Research questions

1. How can the brain contribute to the temporal creation of sets of behavioral layers?
   - Probably co-involvement of sensorimotor areas
2. How are the various forms of precedence relations being set?
   - Probably co-involvement of frontal areas

How could such questions be studied empirically in a non question begging way?

What role could DST play in facilitating the translation from metaphors to empirical research questions?

Functional clusters

- Just an example
- “Elements within a neural system that strongly interact among themselves but interact much less strongly with the rest of the system” for a brief amount of time
    - (Edelman & Tononi, 2000, p.120, see also pp.184-185).
- “A process, not a thing or a place, and it is defined in terms of neural interactions, rather than in terms of specific neural location, connectivity or activity.”
    - (Ibid. p.144)
  - Does not refer to a unique, invariant set of areas in the brain
  - Spatially distributed & changing in composition
  - Exist only temporarily (100 msecs)
  - Recruited for the specific occasion (context, goals)

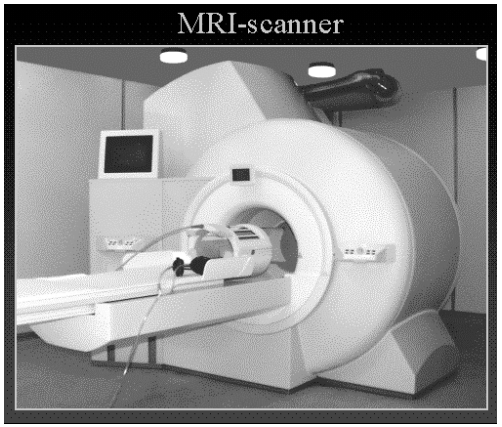
Traditional experimental setups

- Stimuli
  - Recognizing a picture of a cow is not recognizing a cow

  - Randomization
    - Potential effects of previous behaviors and perceptions on the current trial are cancelled out by averaging over trials
    - No realistic history or context
  - 'Resetting' after each stimulus
    - Measure the isolated response to one stimulus
    - No perception-action cycle or perceptual flow (Gibson)
    - Cutting up real-time into parts

Limited body movements

- Complexity of the potential behavior is kept unrealistically low
  - Button pressing creatures
- Subject might even have to devote neural resources into suppressing actions that follow naturally out of the stimulus flow but are not allowed



Wanted: Cognition in the wild

- Different taxonomy and different primitives of behavior
  - Naturally flowing sequence of events and actions
  - Ballard's eye & hand body trackers of complete movements
- No more constraints than necessary for control and replicability of the task as it exists 'in the wild'
- Anthropological and ethological field studies
- Intermediate possibilities
  - Computer games and virtual reality type environments

Cognition in the Wild: Jelle solving the problem of opening a melon without pocket knife

Brain observations in the wild?

- fMRI lacks ecological validity and is on too slow a timescale (seconds)
- EEG outside the lab is possible
  - Gevins et al, 1995, 1998; Berka et al, 2004
  - Still lots of noise and movement artifacts
- Any suggestions?
  - Not unlike searching for alternative energy sources
    - Perceiving the need constitutes part of the solution

EEC & Cognitive neuroscience

- What does the opposition consist of?
  - Central abstract system vs sensorimotor laden cognition
  - Flowcharts based on fixed modules vs more dynamic & interactive modes of operation (functional cluster-like)
- Is an embodied embedded cognitive neuroscience
  - Possible in principle? Yes, but skip the brain-centeredness
    - What would it look like?
      - Not (primarily, ultimately) based on decomposition-localization
      - Task-metaphor for auto-pilot behavior:
        Traffic regulation of temporarily existing behaviors
      - Dynamically coupled style of operating
  - Possible in practice? Yes, but
    - Very different experimental set-ups
    - Current measurement techniques not sophisticated enough (yet)