THE EMERGENCE OF MODERN HUMANS

WHEN HOW AND WHY DID EMERGE THE EXTRAORDINARY COGNITIVE CAPACITIES THAT ALLOWED US HUMANS TO CHANGE THE WORLD

PLAN

1- Facts

- Identify the human capacities and distinguish them from animal ones, as well as from
- Hominin protocapacities: thus dating our emergence as cognitive modern humans

2- Theoretical proposition

- Propose the novel mental process involved
- Infer the novel mental operation allowing the process, as well as
- possible brain mechanism that could underlie that mental operation (latching)

3- Experimental search

- Identify the proposed human mental operation in a lab. experiment
- Explore with imaging observations the underlying brain mechanism

4- Developmental and anthropological aspects

- If late phylogenetically also late onthogenetically?
- Understand how and why that brain mechanism could have emerged in an already anatomically modern homo-sapiens
- Possible connection between neural and subjective aspects of the human psyche

Human cognitive capacities

- Language
- Tools and instruments
- Signs, signals
- Dynamic concepts
- Aeshetic sense
- Metarepresentations
- Logic and algorithmic rules
- Categorization & organization
- Theory of mind
- Anticipatory planning

General consensus of paleoanthropologists for a behavioral revolution 70-40 kys ago

- Modern cognitive human reprocesses the world around him using an immense variety of mental symbols.
- No speciesation
- No classical natural selection mechanism
- Exaptation?

Our (reductionist) intention:
reconduce to changes in underlying mental process and propose a brain mechanism without structural changes

Reprocessing large variety of symbols implies a novel mental process: abstract projectuality

Mental process	Basic characteristics
Abstract projectuality	•No need of sensory stimuli •Novel goals •May require new strategies •Recursivity •Potential time protraction •Eventual discontinuity •Mental effort •Fluent non routine thought

Difference with concrete projectuality

Any mental process consists of a succession of mental operations

Mental operations

essentially shared with mammals & apes

- Automatic: non conscious (3d visual reconstruction, equilibration, etc.)
- Routine: learned, conscious, no cognitive effort, superposable (driving, speaking, singing, etc)
- Supervisory: non-routine operation, modulates one/ more routine op., involves cognitive effort, non superposable. Represents a strategy, implying an optimization with a # of pertinent parameters

MENTAL OPERATIONS HAVE A RATHER WELL KNOWN BRAIN BASIS

BASIC PROPOSITION

D.A.&T.Shallice; Cognition 103(2007)358

- THE HUMAN NOVEL MENTAL OPERATION, ALLOWING ABSTRACT PROJECTUALITY, IS TO CHANGE STRATEGY IN PURSUING A PROJECT WITHOUT NEED OF EXTERNAL INPUTS.
- Implies a supervisory process to latch another one that may operate in a different space of parameters, use other instruments, have different subgoals
- Succession of strategies allows fluent sequence of reprocessings to set, explore and realize complex projects using a variety of cognitive instruments
- Implies metarepresentation

A new mental operation with the same brain structure?

Possible underlying brain process (latching)

- Latching from a phase transition in the brain
- Connectivity as critical parameter
- Long range coherent correlations
- Supported by a simple connectionist model (Treves,Cog.Neurops.22(2005)276)
- Late phylo and ontogenetic development
- Connectivity conditioned by epigenetic and extrasomatic influences

Towards experimental search for latching

- Clear identification of strategy change without hints in lab conditions
- Imaging (fmri) observation of concomitant brain process

The subtraction game

- A two players game (or a participant against the computer)
- G(n,k) : n cases, each player moves forward, in turn, from 1 up to k cases. First player starts from first case
- The player that gets to the nth (last) case wins

Backwards induced analysis:

- Call p_i the participant's position at move i
- To win he should get at n at his last move l, thus $p_l=n$
- To make sure he will be able to move there, he should have reached $p_{l-1}=n-(k+1)$ at l-1 move
- Recursively $p_{l-2} = n – 2(k+1)$ …… $p_1 = n – (l-1)(k+1) < k$

  So if $p_1>0$, who starts moves there and wins. If $p_1 = 0$ it's the second player that wins by moving at $p_2 = k+1$ from wherever the first player has moved first
- For G(15,3) the three winning positions are $p_1=3$, $p_2=7$, $p_3=11$ (3,7,11). For G(17,4) they are (4,7,12)

Subtraction Game Test

(Seyed-Allaei,D.A.,Shallice, Thinking&Reasoning 16(2010)308)

- 36 participants (9 for each of 4 computer set ups), normal SISSA staff, students, secretariat
- 4 computer set ups: (fast & slow) x (early & late)
- Start with instructions for G(15,3), then 15 games (with no time limit)
- Follow with instructions for G(17,4), then 15 games
- Response times & mouse movements recorded
- Everything participants say is recorded, final comments requested
- At few random moments participants asked to comment what was in his/her mind at last move

Analysis and Results

- Strategies identifiable through protocol & debriefing analysis
- Limited influence of different computer set ups

- All 36 participants started by exploring: no one straight to backwards induced strategy
- 18 did not solve the problem, kept exploring without any winning strategy (the three winning positions in at least a game) emerging; i.e. did not enter the game
- 18 got the winning positions in at least the second game: 3 of them through only exploration (strategy I) up to the end, 15 by shifting in a well identifiable moment to a backward induced (strategy II). The changing moment is distributed among participants: with a concentration shortly after starting with G(17,4)
- Thus clearly recognizable strategy change of nearly all engaged participants.

Towards fmri observation of brain processes underlying the strategy change observed with behavioural methods in lab condition

- No possible averaging over trials: needs single trial analysis
- Try multivariate methods in simpler tests
- Our trials have subsequent phases (exploration, recognizing successive winning numbers, starting again with the new game, change strategy, computing winning numbers, etc.)
- Try first with a test having several phases/trial but with possible trial averaging

Brixton test

- Find the rule governing a succession of cards.
- Phases/rule: recognizing a new rule, rule searching, rule finding, rule application
- Usual fmri data averaging over 25 rules gives dorsolateral active in searching, frontopolar for finding+implementing (Crescentini, Seyed-Allaei, DePisapia,Jovicic,D.A.,Shallice,J.Neuroscience.2011)
- Multivariate methods for single trial analysis fail: thus need a better data treatment

A novel technique for analyzing fMRI data

D.A.,F.Baftizadeh,A.Laio,M.Maieron

fMRI: 100.000 voxels, intensities $v_i(t)$ measured every 2 sec. for total time of few minutes. Data driven method:

Identify brain voxels with similar time activation $v_i(t)$

Similarity measure of voxels i and j: define a distance

$$d_{ij} = \sqrt{\sum_{t=1}^{T} (v_i(t) - v_j(t))^2}$$

For each voxel define a density (# of voxels within a distance d_0)

Clustering voxels around local density maxima

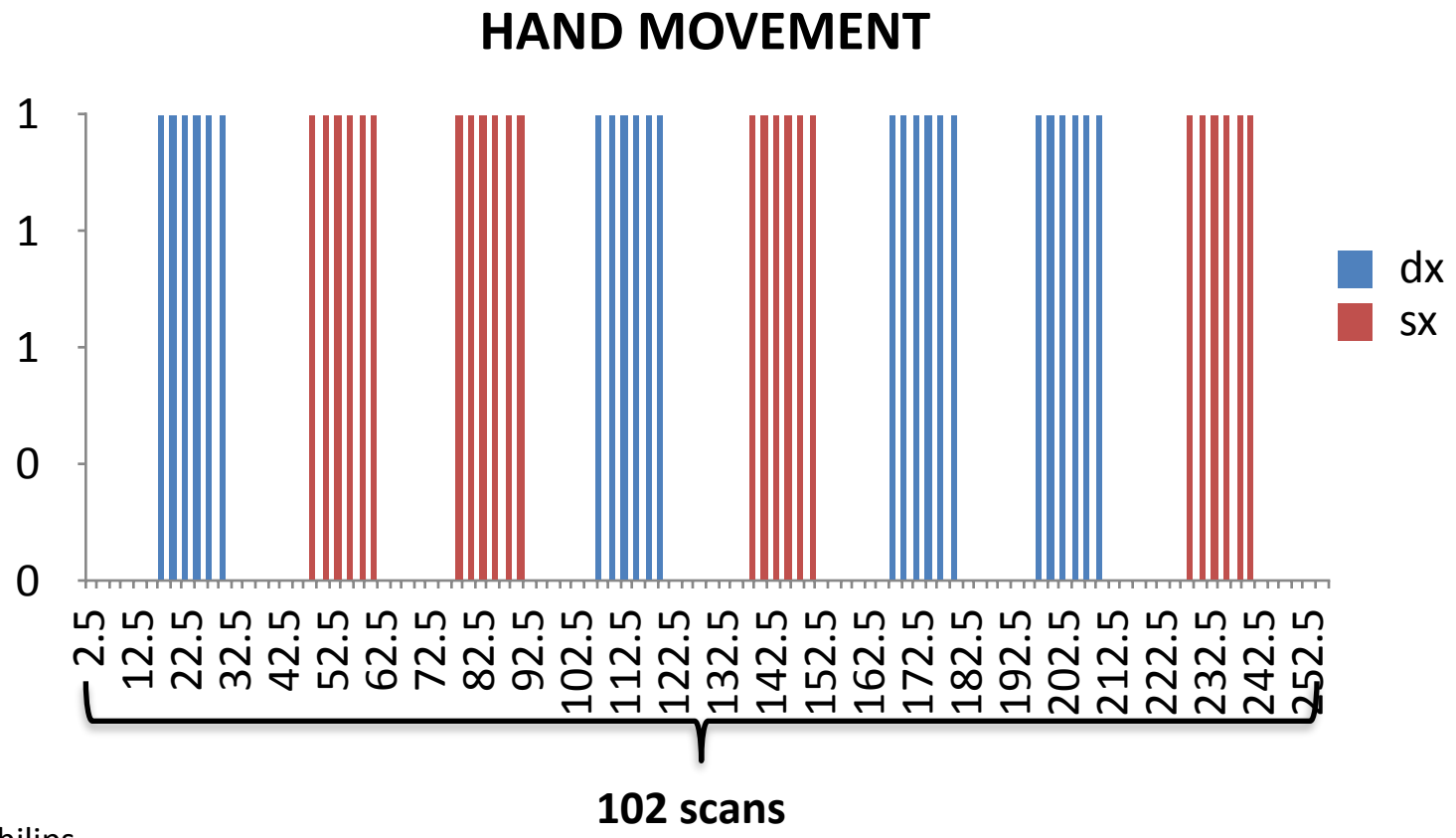
In simple test: leading cluster already shows expected involved brain regions

Better results (practically no noise) for small time windows

Analysis qualifies for single trial applications

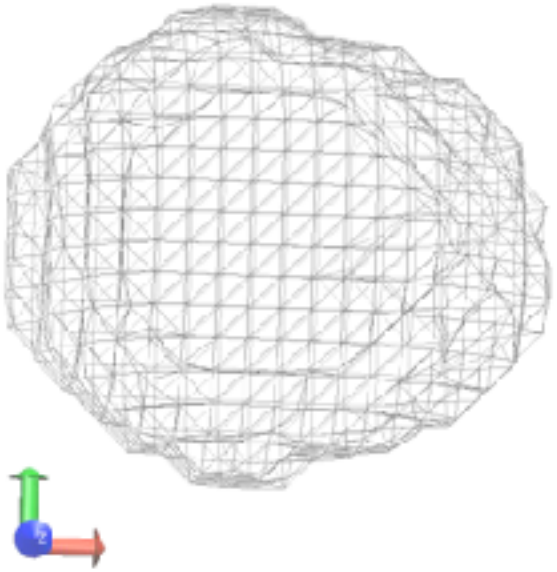
Results: hand movement

The subject was scanned while moving the right or left hand. They saw the words "move left", "move right" or "stop" in a random fashion through the glasses.



3T Achieva Philips
T2* BOLD–sensitive gradient-recalled EPI sequence
standard Head Coil 8 channels
TR/TE = 2500/32 ms
matrix 128X128 , in-plane resolution 1.8 X 1.8
#slices 34, thickness = 3mm, no gap

Right is frontal, left visual cortex, up and down right and left hand



Developmental aspects
If late phylogenetically also late ontogenetically?

Subtraction and Hayling tests in chidren 8-10 years(none) and adolescents of 14-15 years (all)

D.A., Seyed-Allaei, unpublishable

Anthropological aspects

- Cultural influences to connectivity add to evolutionary ones to overcome threshold
- Why 40-70 kyears ago
- Universality
- Possible common origin of human neural and psychological aspects D.A.-Neuro-Psychoanalysis