Messy Minds: Embodiment, Action, and Explanation in 21st Century Cognitive Science

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Preamble = a lesson from Artificial Evolution,

First, the typical scenario

Genetic algorithms operate upon a population of bitstrings encoding candidate solutions to some problem.

An initial random set is **assessed against a fitness function** and the best (probably very bad) are selected, mutated, crossed-over etc to form the next generation, and the **cycle of breeding and assessment** continues until (hopefully) success is achieved.



An Instructive Variant, "Evolutionary Electronics"

= the use of artificial evolution to evolve not just bitstrings but **real electronic hardware** (see Adrian Thompson et al (1996) (1998)).

Specifically, reprogrammable silicon chips (FPGA's)

Goal: To solve a simple problem (distinguishing two tones) that usually requires the use of a few hundred simple circuits on the chip (logic blocks).

But in this case, the candidate solutions were implemented, and the key fitness tests run, using **specific real (reprogrammable) silicon chips**

So each evolving solution was keyed to a **unique real-world chip**.

Results

The best evolved hardware chip (after about 4000 generations) performed the task.

It used **just 37** of its 100 logic blocks and somehow succeeded **without access to a clock to time and sequence operations**.

The logic blocks (Bellows (2007)) were arranged "in a curious collection of feedback loops" and "five individual logic cells were functionally disconnected from the rest- with no pathways that would allow them to influence the output" And a **PUZZLE**:

disable any of the 5 'functionally disconnected' logic blocks and the chip **ceased to function**!

Plus the solution could not be 'run' on any of the other 49 reprogrammable hardware chips in the population.

Explanation = the power of Leakiness and Mess

The evolved circuits turned out to exploit **all manner of physical properties, some specific to that very chip**, of the kind usually ignored or deliberately suppressed by human engineers.

Eg the 'disconnected 5' were interacting with the main circuitry through a kind of **leakage** ('magnetic flux').

And most of the blocks were acting in hard-to-understand, non-linearly interacting, **analogue fashions**, not as simple on/off switches.

"It can be expected that **all of the detailed physics of the hardware** will be brought to bear on the problem at hand: time delays, parasitic capacitances, cross-talk, meta-stability constraints and other low-level characteristics might all be used in generating the evolved behavior" Thompson *et al.* (1996), p. 21.



And the exploited properties **don't have to stop inside the chip....**

In later experiments (Bird and Layzell (2002)) a circuit was evolved to produce an oscillatory signal, again without any internal clock.

It **evolved a radio receiver** to 'steal' information specifying a clock signal from a nearby desktop computer!

(for further discussion, see Pfeifer and Bongard (2007) pp 189-192) The Moral: Nature is happy to use any properties, drawn from any level, type, or location, of physical functioning, if they help to solve the problem.

It is not committed to firewalls, neat modules, or singlepurpose components. It doesn't even care about what's inside the organism versus what's outside.

It is not interested in building systems that are easy to understand, rebuild, or take apart.

All that matters is recruiting a motley of resources apt to support cheap **online success**.

Idea of the talk

To explore this kind of 'messy, leaky' processing profile as it arises in respect of cognitive contributions from the **body**, from **action**, and from **the world**.

And to ask what this means for our attempts to explain and understand the mind itself.

Can there be a systematic science of 'messy minds'?

Do we still have a grip on what the **mind and self can be**, when these 'messy' solutions allow cognitive processing to bleed into the gross (non-neural) body and world?

Does 'embodied cognition' really name a **new unified field** of research, or will the 21st Century be the time when we have to give up on the very idea of a unified science of mind and cognition?

Embodied Cognition

A new and unifying perspective for the sciences of mind?

Or maybe just

"a lexical band-aid covering a 350 year old wound generated and kept suppurating by a schizoid metaphysics"

Maxine Sheets-Johnstone (1999 p.275)

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Key idea: **control and information processing** are not restricted to the brain/CNC

Bodily structure and activity may be exploited, in all manner of unexpected ways, as an essential part of an information-processing organization.





Consider the role of the **tendon network** of the hands in the calculation of finger motion.

Using a combination of real-world cadaveric experiments (here, experiments using fresh cadaveric hands resected at the mid-forearm) and computer simulations, Valero-Cuevas et al (2007) demonstrate the existence of anatomically distributed informationprocessing for the control of finger motions.



Valero-Cuevas F J, Yi JW, Brown D, McNamara R V, Paul C, Lipson H (2007), "The tendon network of the fingers performs anatomical computation at a macroscopic scale", *IEEE Transactions on Biomedical Engineering*, pp. 1161-1166. V-C et al show that the control of apt finger motion is **not enabled solely by the nervous system** but involves complex and essential contributions from the network of linked tendons such that:

> "the distribution of input tensions in the tendon network itself regulates how tensions propagate to the finger joints, acting like the switching function of a logic gate that nonlinearly enables different torque production capabilities"

Valero-Cuevas et al (2007) p 1161

Roughly:

The tendon network **itself** acts like a kind of logic gate performing a **nonlinear switching function** affecting the way that tensions propagate to the finger joints.

Such a function, *were it performed by the nervous system itself*, would unproblematically be counted as part of the evolved cognitive control apparatus. (for discussion see Valero-Cuevas et al (2007) pp 1165-1166).

= a case of what Pfeifer and Bongard (2007, p.100) call **'morphological computation'**

"bodies can perform functions that would otherwise have to be performed by brains" It is not just that the load is spread, but that the *control function* itself is distributed across the nervous system and tendon network, such that:

"part of the controller is embedded in the anatomy, contrary to current thinking that attributes the control of human anatomy exclusively to the nervous system"

Valero-Cuevas et al (2007) p 1165

First Open Question:

Is this best seen as a form of genuine computation (e.g. Pfeifer and Bongard on 'Morphological Computation') or as a **non-computational** way to achieve results that might otherwise be expected to involve computation?

(For some discussion, see Lukas Sekanina 'Evolved Computing Devices and the Implementation Problem' in *Minds and Machines* 17:3:2007)

Either way, provides a simple example of **non-trivial causal spread**

Cases where something (here, aspects of torque calculation that) we might have expected to be achieved by a certain well-demarcated system (the brain/CNS) turn out to involve the canny exploitation of a variety of other factors and forces.

(for lots on that, see Wheeler and Clark (1999), and Wheeler (2005)

Another example: ASIMO versus Passive Dynamic Walkers



Honda's Asimo 'The most advanced humanoid robot in the world" 26 degrees of freedom. Mobile, embodied, yet the role of the body remains thin..

Consider energy efficiency....

Energy efficiency can be measured via 'specific cost of transport' (energy used)/(weight)(distance traveled) = 'the amount of energy required to carry a unit weight a unit distance.

SCORES (the lower the better: taken from Collins and Ruina (2005) **Asimo: 3.2 Typical Human: 0.2.**

WHY? ASIMO micro-manages each joint angle, and expends lots of energy holding the whole show in place. ASIMO's body is just one more problem to be (micro)managed...

Compare: Passive Dynamic Walkers (PDW's)



(Andy Ruina Lab, Cornell: original work by Tad McGeer)

No actuation except gravity, and no joint angle control at any time

Inner and outer legs are paired to constrain it from falling over sideways.

Surprisingly, PDW's are capable (when set on a gentle incline) of **very stable, human-looking walking**.





A third generation Passive Dynamic Walker.

By S. Collins (prototype)

Here, the body IS part of the solution.

Q/ How to build on this kind of fluency in a powered walking device?

A/ Rely on a control regime that systematically **pushes**, **damps and tweaks** a system in which Passive Dynamic effects continue to play a very major role = **control as a gentle nudge to a complex system**.

In this way, a low energy source, a simple control system, and the body (and gravity!) can 'collaborate' to solve the walking problem.

= the power of **co-evolving morphology (shape) and control.**

"Efficient Bipedal Robots Based on Passive-Dynamic Walkers" S. Collins, A. Ruina, R. Tedrake, M. Wisse Science 307, 1082 (2005)

= a 'new design and control paradigm' (op cit p 1083) for walking robots







'Robotoddler' (Russ Tedrake, MIT, 2005)

Learns a control policy that exploits the passive dynamics of the body.

change speeds forward and backward **different terrains**

(power consumption 1/10th that of Asimo)



Sparse but well-timed control signals enable fluent, energyefficient roll and rise..

Kuniyoshi, Y., Ohmura, Y., Terada, K., Nagakubo, A., Eitoku, S. and Yamamoto, T. (2004)..



Iida and Pfeifer's PUPPY (2006)



Even Puppy's **aluminum legs and feet** play an adaptive role: they induce small amounts of **slippage** on most surfaces.

Reducing the slippage by adding rubber pads to the feet actually caused the robot to begin to fall over!

The subtle slippage was actually playing a stabilizing role, effectively enabling the robot to rapidly search for a stable way to proceed

(see Pfeifer and Bongard (2007) pp 96-100, 125-128 for discussion).

An important observation (Pfeifer and Bongard, 2007)

Complex morphologies (eg combinations of legs, muscles, and tendons rather than simple wheels) determine more complex, richer **"uneven" landscapes for control.**

This is because the bodily biomechanics themselves determine a number of **stable (minimal energy expenditure) gaits** such as jumping, running, walking, trotting, and skipping, which the system repeatedly falls into **given its motor speeds and the local terrain**.

(recall Scott Kelso and colleagues classic work on fingerwiggling)
These biomechanically constituted 'attractor states' can form the basis for **high-level control strategies** which can simply 'assume' that the system will tend to fall back into these states whenever it is brought close to one of them.

In this way we get by with **nudges and tweaks to a system with rich intrinsic dynamics**, rather than more **complex commands to a system with simple intrinsic dynamics**.

First Moral of the Messy Mind: **control and processing leak into the body...**

Bodily shape (morphology) and bodily bio-mechanics re-configure a wide variety of problems in ways that promote fluidity and efficiency by simplifying the neural commands required to bring about complex behaviours, effectively delegating aspects of control and processing to the body itself.

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Action: it is not just the gross form and bio-mechanics, that may be doing unexpected work, but also the skilled use of the body in action.

Lots of work on this as **'enaction' paradigms** (Noë, Varela, Thompson, etc) sweep philosophy and cog sci.

But I think the key contribution of action really concerns the power of what Lungarella and Sporns (2007) call the **active self-structuring of a data flow**

Very obvious in child development: eg grasping, poking, pulling, sucking and shoving creates a **rich flow of time-locked multi-modal sensory stimulation**.

Great for learning about objects



A simple example: BABYBOT (Metta and Fitzpatrick) learns about object boundaries by poking and shoving.

= simple idea of **searching for spread of motion activity**.

BABYBOT moves its arm and it's visual system can detect that motion.

If there is a **sudden spread of the motion outwards**, that means that the arm has **encountered**, **and is now pushing**, **an object**.

So the BABYBOT's own motor action has now induced an **informative sensorimotor correlation**: the sudden **spread of motion identifies the boundaries of an object**.



Nor is this just a trick for babies:

We are rampant self-structurers of our own information flows.

Even during 'higher cognition' we may sketch, scribble, gesture, and talk to ourselves, creating flows of visual and auditory stimulation that can help structure and guide our own congitive activity.

An interesting case: the (possible) **role of physical gesture in the process of thought**

Goldin-Meadow (2003) McNeill (1992) (2005)



Q/ Might the active hands and arms, during non-iconic, spontaneous gesture, count as genuinely **part of the process or mechanisms** of thinking. Or are the physical acts only there for communicative purposes?

Some clues that gesture might be part of thought include:

- that we do it when talking on the 'phone
- that we do it when **talking to ourselves**
- that we do it **in the dark** when no-one can see.
- +
- gesturing increases with task difficulty.

•gesturing increases when **genuinely reasoning about a problem rather than merely describing** the problem or a known solution. "Just a residual association? Or done for an imagined listener?"

BUT:

•Speakers **blind from birth**, who have never spoken to a visible listener, and never seen others moving their hands as they speak, gesture when they speak.

•Moreover, they do so **even when speaking to others they know to be blind** (Iverson and Goldin-Meadow 1997, 1998, 2001)

Might our gestures be doing cognitive work?

A possible model (drawing on McNeill, Goldin-Meadow, Gallagher, Hutchins, Vygotsky)

In gesture, as when we write or talk, we **materialize our own thoughts**...we bring something concrete into being, and that thing (in this case, the arm motion) can **systematically affect our own ongoing thinking and reasoning** (see Clark 2007 for some discussions of how this might work as a form of analogue encoding)

This is what Dennett (1991) calls the power of **'cognitive self-stimulation'** and I describe as a kind of cognitive turbo-drive

(and see especially McNeill in his (2007) *Gesture and Thought*)

The Turbo-Drive Model (Clark (2007))

Compare: the car makes exhaust fumes that are systemic outputs that are also systemic inputs that drive the turbo that then adds power (up to around 30% more power in some cases) to the engine.

The exhaust fumes are outputs that are also selfcreated inputs that despite their status as outputs **also form a proper part of the overall power-generating mechanism**

Note for Philosophers:

Reflection on the Turbo model suggests that just because some X is visibly an output, (eg an **action**) and processed as an input (e.g. a , **perception**) that does not mean that that X cannot **simultaneously be part of a process that is cognitive.**

It is just a flip in perspective on the same events.

Suggestion is that the actual physical gestures thus act as elements in the cognizing system.

Gesture is not merely an outflow: it is part of the process, the mechanism, of the thinking

Speech, gesture and neural activity continuously inform and are informed by each other, together constituting a **single integrated cognitive system** (Iverson and Thelen (1999)) McNeill (2005) is especially clear, writing that:

"the gesture, *the actual motion of the gesture itself*, is a dimension of thinking" (McNeill (2005) p.98, stress in original).

Neural systems **co-ordinate with, produce, exploit, and can in turn be affected by**, these gross bodily motions.

Upshot = "a dynamic mutuality [involving words, gestures, and neural activity] such that activity in any one component of the system can potentially entrain activity in any other" Iverson and Thelen (2001) p.37

A general picture:

At many levels, **self-generated motor activity** acts as a "complement to neural information-processing", creating whole, highly complex, systems of **non-linear re-entrant processing** in which

"information structuring' by motor activity and 'information processing' by the neural system are continuously linked to each other through sensorimotor loops"

Lungarella and Sporns (op cit) p.25

Second Moral of the Messy Mind

Cognition leaks into whole action-perception loops.

The presence of a self-controlled, acting, sensing body allows an agent to **sculpt (and sometimes entirely to create) her own sensory input streams** in ways that promote learning, reasoning, and efficient problem-solving.

The engine of some forms of cognizing is thus not the naked brain, but a **complex whole involving the brain in concert with the sensing acting body.** And it doesn't stop there...

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An old favorite: The (Bluefin) Tuna Puzzle

The aquatic performances of bluefin tuna **far outpace their basic physical powers**.

They simply should not be able to go as fast as they do, to turn so sharply, to blast off so powerfully, etc.

Too weak by **about a factor of 7**.

(work by Triantafyllou brothers at MIT)

The tuna use **naturally occurring eddies and vortices** (eg where water hits a rock)

And they use **tail flaps to actively create local vortices and pressure gradients that they then exploit** for rapid start-offs etc

Efficiency way over 100%, tested using a 49 inch anodized aluminium and lycra robot tuna in a tank at MIT





That may seem far away from the refined cognizing of the human mind.

But our own use of **external operations and media** to enhance our problem-solving powers is quite like the tuna's active creation and exploitation of watery vortices.

We write **words on a page, or draw a diagram that we ourselves inspect**, so as to productively alter the flow of thought.

Just as the Tuna structures its world to promote better swimming, we structure our worlds in ways that promote better thinking.

We make our worlds **smart** so that brains like ours can be dumb(er) in peace!

Exchange between Richard Feynman (the Nobel laureate physicist) and the historian Charles Weiner

"Weiner once remarked casually that [a batch of notes and sketches] represented "a record of [Feynman's] day-to-day work," and Feynman reacted sharply.

"I actually did the work on the paper," he said.

"Well," Weiner said, "the work was done in your head, but the record of it is still here."

"No, it's not a *record*, not really. It's *working*. You have to work on paper and this is the paper. Okay?" "

Quoted in *Genius* (Gleick's biography of Feynman)

It is not that all the thinking happens inside, and the loop out into symbols on a page is just a kind of convenience or a way to avoid forgetting.

Rather, the loops to external media, just like physical gestures, form part and parcel of an integrated, if temporary, system for thinking.

(For lots of examples, see Clark (2005) (2006))

"Well done dear old brain. Once more you have pulled me out of a tricky situation, and that last idea of yours may well get me a bonus".



The brain supported **some re-reading** of old texts, materials and notes.

Whilst re-encountering these external traces, it responded by generating a few fragmentary ideas and criticisms.

These ideas and criticisms were then stored as **more marks** on paper, in margins, on computer discs, etc.

The brain then played a role in **reorganizing this data**, **on clean sheets**, **adding new on-line reactions and ideas**.

The cycle of reading, responding and external reorganization is repeated, again and again.

The Naked Brain Fallacy



Giving full credit for intellectual achievement to the biological brain alone, instead of seeing it as **one player on a busy stage** full of props and scaffoldings whose contributions are complex and profound. The moral here: the matter that matters to mind just ain't all in the head.

Human minds are expert at incorporating both bodily and non-biological props and aids **deep** into their problem-solving routines.

We use wristwatches, pens, paper, PC's, calculators, spreadsheets, compasses, diaries, cellphones, reference books, Google, sketch–pads..

And in becoming (if we do become) expert users, we **progressively dovetail** our own neural strategies to the properties and capacities of these cognitive artifacts, creating **profoundly integrated extended systems**.

(for lots on this kind of stuff, see Clark and Chalmers (1998), Clark (2003), Wilson and Clark (In Press))



A strong claim: In such cases, whole brain-body-world ensembles constitute extended cognitive circuits. Such extended circuits are themselves the vehicles of much higher thought and reason e.g. the cases of scribblingas-part-of-thinking, gesturing-as-part- of-reasoning, etc.

= the idea of the **'extended mind'**: (see Clark (1997), Clark and Chalmers (1998), Clark (2003): see also Hurley (1998), Rowlands (2003, 2006), Wilson (2004))

Plenty of historical and contemporary company for claims in this broad ballpark...

Dennett, Hutchins, Donald, Mithen, Wilson, Vygotsky, Varela, Thompson Rosch, Bruner, Norman, Heidegger, Gregory, Gibson, Turvey, **Merleau-Ponty Bateson**just fill in your favourites.... Third (and final) Moral of the Messy Mind:

Cognition leaks not just into the body, but into the world, including (especially) the world of external symbol structures, diagrams, etc.

As a result, some of an agent's cognitive processes are run on special machines constituted by **temporary 'softassembled' combinations of resources spanning brain**, **body**, and world.

Second Open Question

Do we really **add anything** to our understanding of mind and cognition by depicting these larger circuits as quite literally the machinery of some forms of human cognizing?

Or do we get all we need just by seeing the body (as in torque computation and gesture) and the world (as in the scribbling-loops) as **props and tools that allow genuinely cognizing brains to solve more complex problems.**

For some critical discussion see Adams and Aizawa (2001) (In Press) Rupert (2004) (In Press), Clark (2007) (In Press), Wilson and Clark (In Press),

Important but here omitted:

The crucial role of **other agents** in the socio-technological matrix (is the 'extended mechanism' model useful there, or is this a different kind of case?)

Considerations concerning the body and emotion (Damasio (1994), Prinz (2004), Colombetti (2005)).

Important work on **embodiment**, **social interaction and co-ordination** (nicely reviewed in Gallagher (2005)).

Vexed questions concerning the possible role of embodiment and action in **qualitative conscious awareness** (e.g. Thompson and Varela (2001)).

Overall, and regardless of the worms, we are stranger than we think

we are inveterate conjurors of our own cognition-enhancing bodily acts, worldly situations, and input streams.

I think we are still insufficiently impressed by our own oddness in this respect...
Imagine:

A chess machine that kept **talking to itself** (perhaps very very softly) while it was pondering the next move

Or an expert system that, when asked a question, proceeded to print out a few sketches which it then carefully examines using its own cameras, and amends using its own effectors, before issuing a verdict.

Such odd entities would belong, like us, to the space of messy, leaky systems: cognitive engines built to make the most of body and world.

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In the time remaining, I'd like to take a quick look at some delicate issues concerning the **shape**, **scope**, **nature** (and **maybe the very possibility**) of a science and philosophy of messy, leaky, repeatedly soft-assembled cognitive engines.

- How (if at all) shall we understand such systems?
- What does all this mean for the very ideas of mind and self?
- Where does the mind stop and the rest of the world begin?

How (if at all) shall we understand such systems? The Problem:

Many effects here depend on **complex non-linear interactions at multiple time-scales** and span **multiple levels of organization**

These brain-body-world processes are multiply hybrid, involving internal representations and computations, bio-mechanical propagations of force and energy, manipulations of external symbol systems, all held together by sensorimotor loops, and where real timing is often critical.

What tools and perspectives do we need to make sense of this?

One promising 'bottom up' approach is via **robotics** e g work governed by what Pfeifer and Bongard (2007) call the 'Principle of Ecological Balance'.

> "first...that given a certain task environment there has to be a match between the complexities of the agent's sensory, motor, and neural systems...second....that there is a certain **balance or task-distribution between morphology, materials, control, and environment**" Pfeifer and Bongard (2007) p 123

Also, developmental and 'neurocontructivist' approaches

In development brain, body and world interact in complex ways that slowly 'grow' minds like our. **Embodied cognitive growth** as an area ripe for future exploration.

See eg Smith, L and Gasser, M (2005) The Development of Embodied Cognition: Six Lesson from Babies *Artificial Life* 11:1:13-30, and the (2007) two volume *Neuroconstructivism* set by Mareschal et al

And these can combine, as in the Babybot project, and more generally in 'Epigenetic Robotics' (the attempt to explore developmental processes via robotic implementations)

Ideally: epigenetic robotics with complex morphology

(see Pfeifer and Bongard (2007))

All a bit engineering and bottom-up? Sth more fundamental perhaps?

Lungarella et al (2005) investigated (quantitatively) the extent to which the ability to **produce activity that actively structures** the sensory input **increases various information structures present** in the sensory signals themselves.

= the added value of information flow self-structuring

Results: The presence of coordinated self-generated motor activity (when compared to a control condition), resulted in a **suite of measurable differences in the information structure** implicit in the sensory array.

e.g. measurable increases in

mutual information (the statistical dependence of one variable -in the simple experiment, the state of an individual pixel in the visual array- on another)

integration (the total amount of statistical dependence among the variables, hence the degree to which they share information)

'complexity' (measured as the degree to which a system is both functionally specialized and functionally integrated, a property that delivers **maximum information-processing power**. See Sporns (2002)

Third Open Question

Can there be a fundamental theory linking morphology, perception, action and neural control in ways that reveal their co-operative role in the construction and control of intelligent behviour?

If so, what will it look like?

Will it be some version of information theory (Sporns etc)?

(or of dynamical systems theory (Schoner et al)?

or maybe sth with a more economic 'cost-benefit' flavour (Gray et al)?)

On the Horizon?

A **unified science of the mind** encompassing ecological context, action, timing, bio-mechanics, dynamics, computation and representation.

= the good news...

The Bad News?

Once we recognize the profound and ongoing role of the bio-mechanical body and the extra-bodily world in mind and cognition it becomes harder and harder to see where the cognitive machinery of mind and self stops and the (rest of the) world begins.

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A surprising result?

Once we recognize the profound and ongoing role of the (extra-neural) body in mind and cognition it becomes harder and harder to maintain the idea that the skin itself, at least for cognitive purposes, is a crucial boundary.

The 'logic' of **embodiment** casts doubt on the cognitive importance of the **skin**

But this can be unsettling...

A common fear

All this intermingling of brain, body and world risks a kind of **cognitive dissolution**, as we slowly but surely lose track of where the thinking agent stops and the rest of the world begins.

= a kind of personal dissolution into the biotechnological matrix..



A kind of cognitive **BLOAT**



No time to really address the issue, but will make one quick point...

Several critics aim to stop the bloat by appeal to a notion of the biological brain as ultimate controller

"Even if bodily and external elements sometimes participate in processes of thought, reason and decision-making it is always the biological brain that has the final say"

So the brain is the **controller and chooser** of actions in a way all that gross-bodily and external stuff is not. **So the external stuff should not count as part of the real cognitive system.**

See eg Butler (1998), see also Adams and Aizawa (2002)

But I am not convinced.

Re-applying the "locus of control" criterion inside the head helps reveal what's going wrong. Do we now count as not part of my mind or myself any neural subsystems that are not the ultimate arbiters of action and choice?

Suppose only my frontal lobes have the final saydoes that shrink the thinking agent to just the frontal lobes!?

What if **no** unique subsystem always has the 'final say(Dennett)? **Has the thinking agent just disappeared**?

NO

What all this shows is that we need **better notions** of the thinking agent, of control, and of mind and self!

That's where we need more than the lexical bandaid on the suppurating metaphysics.

(for some inadequate attempts, see my *Natural-Born Cyborgs* and Dennett's *Freedom Evolves*) Perhaps it is 'userless tools' all the way down?

Different neural circuits provide **different capacities**, while bodily routines, external tools and technologies add **still further capacities**.

But no single 'tool' is the locus of human thought and reason or the seat of the self

We just are those shifting, 'soft–assembled' temporally interwoven, collections of tricks, tools, and ploys (see especially Dennett (1991) (2003))

We are **'soft selves'** (Clark (2003)) **continuously assembled and reassembled**, qua thinking engines, from a grab-bag of neural, bodily, and worldly elements. A closing story:

Carolyn Baum (head of occupational therapy, Washington University Schol of Medicine) studied a population of **Alzheimer's sufferers** who, despite very low scores on the standard CERAD protocol, somehow **manage to live and cope alone in inner city St Louis**

They shouldn't be able to do so.

Another puzzle

Homes stuffed full of **personalized cognitive props, tools and aids:**

memory books, pictures, important stuff stored in open view, labels on doors, etc etc

And **well-practiced routines** for **using and maintaining** these structures.

You may say/ well, this just confirms the extent of their mental deficit.

But this is too quick/

Imagine a world in which **standard human brains** had that same profile

and imagine we had gradually evolved a society in which the use of these kinds of props and aids **was the norm**. But our own pens ,papers, notebooks, diaries, Palm Pilots and iPhones have evolved to complement **OUR** brute biological profiles in much the same way.









Yet we never say of the successful artist, designer, mathematician or poet:

"Poor soul- she is not really responsible for that lovely painting/ poem/ theorem/ design.

For don't you see how she has had to rely on all those props and scaffoldings to continually offset her own mental inadequacies.."

The Big Picture

On reflection, all this is simply to take a familiar 20th Century theme one step further.

Theme =

That the (presumably neurally-realized) conscious mind is at best just a thin slice of the complex overall machinery of mind and reason

Two Further (21st Century?) Steps:

To see that the role of the many control strands and structures that hold this all together is not to micro-manage but rather to **tweak and nudge a complex distributed system** built of many heterogeneous parts

To see that the 'hidden mass' of complex machinery includes bodily morphology and bio-mechanics, bodily actions that self-structure information flows, and temporary 'hybrid' cognitive circuits spanning brain, body and world. Many (many!) outstanding questions remain:

What is the **basic tool-kit for understanding 'tweak and nudge' styles of adaptive control**, and does this involve the use of **more** than the standard information-processing tools and notions?

What is the **basic tool-kit for understanding hybrid functional wholes, and the complex multi-scaled** processing scenarios in which they participate?

What **extra tricks and tweaks** (both biological and resulting from incremental engineering of our epistemic environments) enable we humans to be such world-class experts at such resource-exploitative control?

What **exactly** happens when biological endowments for adaptive control **interact with material symbolic artifacts** such as spoken words and written inscriptions?

Given all that **productive permeability**, how should we best **identify and analyze minds**, **persons**, **agents**, **environments**, **and perceptual and cognitive systems**?

What about the **cognitive/non-cognitive** divide itself: does it still make sense when everything is just a **resource on a level playing field?**

But a positive moral nonetheless:

The mess is good!

Messy-minded agents exploit bodily and bio-external sources of order and structure for **control**, **encoding**, **processing**, **reasoning**, **and memory**.

Considered as cognitive engines, we are thus prone to constant and repeated episodes of **soft assembly**, **extension**, **revision**, **and re-construction**.

This reveals sth of who and what we are..

Creatures who are truly OF our world and not just IN it.

