DISTRIBUTED MEMORY, COUPLING, AND HISTORY

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ABSTRACT
A case study in historical cognitive science, this paper addresses two claims made by radical proponents of new dynamical approaches. It queries their historical narrative, which sees embodied, situated cognition as correcting an individualist, atemporal framework originating in Descartes. In fact, new Descartes scholarship shows that 17th-century animal spirits neurophysiology realized a recognizably distributed model of memory; explicit representations are patterns of spirit flow, and memory traces are changes left by experience in connections between brain pores. This historical sketch supports the second dynamicist claim, that connectionists' stress on the cognitive importance of pattern-recreation needs supplementing by dynamicists' real-time focus and attention to the active roles of body and environment. Animal spirits theory exhibits just the 'continuous reciprocal causation' between brain, body, and environment which Andy Clark sees as dynamicism's central contribution, and allows for the embedding of brains in culture as well as the physical world.

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1. INTRODUCTION: HISTORICAL COGNITIVE SCIENCE

New dynamical approaches to the sciences of mind, hope their most fervent proponents, will bring "a revolutionary change in the intellectual culture of cognitive science" (van Gelder and Port 1997:139). In taking up the challenge to develop decentralized pictures of cognition and control which take time, body, and world seriously, it's not enough, we're told, merely to add new dynamical techniques, simulations, and theoretical insights to our existing repertoire: rather one must undergo a certain severe perspectival change, "a fundamental shift in one's theoretical worldview" (ibid, 135). According to this rhetoric, then, the scope and vision of cognitive science itself must again expand: alongside developments in robotics, developmental psychology and so on, the general intentions to examine the "seepage of the mind into the world" (Clark 1997:214) and to "think of cognition as essentially a matter of *change in time"* (van Gelder and Port 1997:135) will also alter our thinking on culture and personal identity.

If such big talk is to be backed up, we need to find converging lines of thought from other disciplines, demonstrations that cognition and culture can indeed be reconceptualised together. There are already signs of a confluence of research between dynamicism and cognitive anthropology. I think not only of Hutchins' integration of ethnopsychological fieldwork with neural net modelling of group dynamics in studying "cognition in the wild" (Hutchins 1995), but also of the use of connectionist versions of schema theory to model cultural internalization and socialization (D'Andrade 1995:136-149; Quinn and Strauss 1997). But the parallel notion of a **historical cognitive science** seems bizarre: how could dead men's theories help in our contemporary sciences of mind?

One of the few points which unites the wide range of cognitive scientists impressed by the radical potential of dynamical hypotheses is their shared opposition to a "generically Cartesian picture of the nature of mind". Descartes' errors must, they repeatedly claim, be more thoroughly overcome: not just his dated dualism and his division of cognition from affect, but his deeper picture of cognitive processes cut off from the world, in "a realm whose essence owes nothing to the accidents of body and surroundings" (van Gelder 1995:379; Clark 1997:xi). Neglecting contingency, embodiment, and culture on Cartesian grounds, cognitive scientists, we're told, have retained Descartes' persistent, insidious explanatory divides: "perception, thought, and action must be temporally distinct and theoretically separable", while both world and body can be practically discounted, the former as merely a source of input to the internal cognitive system, the latter as merely "a courier system" for sensory and motor messages (Wheeler 1995:67).

Firstly, then, and most obviously, a historical cognitive science can critically examine the textbook accounts of Descartes' individualist picture of cognition on which these dynamicists' comments rely: they are highly selective, if not simply wrong. I draw on revisionary Cartesian scholarship to argue that Descartes models many cognitive processes on fluid dynamics, that his distributed model gives central place to the plasticity and causal holism of learning and memory, and that he sees these processes as reciprocally joined, or coupled, with bodily and environmental processes.[1]

Such a reversal of our received wisdom about Descartes' views is of interest in its own right, and I hope that it figures on the list of the most outrageous claims of this conference. But there is more to it than merely the scholarly rehabilitation of the much-maligned evil demon of modern philosophy of mind. Historical data, I argue, can make positive contributions to substantive debates within cognitive science. Here I use strange historical theories of memory based on the motions of physical animal spirits[2] through the pores of the brain to support three related claims: that distributed models of memory and learning are psychological models operating "at a decidedly abstract level" (Churchland and Churchland 1996:225); that there is a more natural intimacy between dynamics and distribution than some allow[3]; and that what

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[1] The historical material in sections 3 and 4 below draws on an extensive account of 17th- and 18th-century theories of memory in Sutton 1998a:50-113, where I also answer objections to my interpretation of Descartes.

[2] Animal spirits are, paradoxically, neither animals nor spirits, but the neural fluids which were generally thought to be the medium of nervous transmission before the establishment of animal electricity after Galvani's experiments in the1780s.

[3] Careful reading of van Gelder's work reveals his agreement on this point, and suggests that we shouldn't read any **principled** dynamicist hostility to connectionism into the complaint that much connectionist research is still "a kind of ugly hybrid of dynamical and computational elements" (van Gelder and Port 1997:3; cf 1995:32-34). I show that, in the historical

Hume would call "the Cartesian philosophy of the brain", far from supporting the nasty, rationalist "original sin of modern philosophy" (R. Rorty 1980:60), brought the processes of learning and memory into intimate, dynamical relations with environment and culture.
The strategy, then, is to take further the implications of the dynamicists' vaunted "post-Cartesianism" (van Gelder 1995:379-381), but to do so in part through Descartes' works. Clearly the project requires us to understand "dynamicism" in cognitive science very broadly: its application cannot be restricted to views which employ twentieth-century mathematical tools. This is, I believe, justifiable: the results of this exercise in historical cognitive science reveal significant similarities in orientation and emphasis between old and new dynamicisms.

2. THE FRAMEWORK AND ITS REALIZATIONS

A single abstract framework of patterns and transformations is shared by old and new distributed models of memory. Both critics who complain that connectionism is just a technology-driven fad, and connectionists who rest their case wholly on "neural plausibility" misunderstand the generality of this framework: neither biological neural nets nor massively parallel silicon architectures are essential to its psychological power. Instead, as the Churchlands put it (1996:226-7),

> What is essential is the idea of fleeting high-dimensional patterns being transformed into other such patterns by virtue of their distributed interaction with an even higher-dimensional matrix of relatively stable transforming elements. The fleeting patterns constitute a creature's specific representations of important aspects of its changing environment. And the relatively stable matrix of transforming elements constitutes the creature's background knowledge of the general or chronic features of the world.

So we have, on the one hand, an enduring but modifiable architecture; and, on the other hand, sequences of transient patterns unfolding over time. Within this framework, occurrent or *explicit representations* are the passing patterns of activity (vectors or motions) evoked by the combination of previous activity pattern, patterns of connectivity and connection weights between the elements, and current input. *Implicit representations*, in contrast, are learned dispositions in the elements and in the connectivity weight matrix, dispositions which partly determine the construction of the explicit patterns of activity.[4]

Nothing in this theoretical apparatus ties it uniquely to (natural or artificial) neural nets. Neural nets are among a set of possible physical realizations of this apparatus, which is thus conceptually independent of these realizations. This can be confirmed by describing a different realization in animal spirits theory (section 3 below). We'd expect to find in this alternative context not only the basic apparatus of patterns and transforming elements which ground the explicit and implicit representations, but also evidence of **superpositional storage**, the key to a distributed model of memory. A memory trace is **extended** when it's spread across a number of elements, with many elements involved in one representation. But extendedness is not enough for distribution, since every trace could still be quite distinct, entirely independent of the set of elements composing every other trace: **superposition** too is required (van Gelder 1991). To take one clear definition, "two representations are fully superposed if the resources used to represent item 1 are coextensive with those used to represent item 2" (Clark 1993:17). Superposition, which is thus a matter of degree, provides an internal structure to representational space: many slightly different implicit representations are superpositionally piled in the same system, with many "representations" in one "representing" (van Gelder 1991). There's nowhere for traces to stay between experience and remembering: every explicit tokening of a pattern of activation is a construction. Data disappear after a pattern has been processed, persisting "only implicitly by virtue of the effect they have on what the network knows" (Elman 1993:89). This learning mechanism, notoriously, allows both flexible

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case at least, it was the key connectionist notion of superposition which in fact grounded just the right kind of dynamical perspective on mind, body, and world. Throughout this paper I refer only to that (large) subset of connectionist models which employ distributed representation, and to that (smaller) subset of dynamical models which are recognisably connectionist.

4 This connectionist distinction between explicit and implicit representations is, of course, quite different from that found in the localist framework of classical cognitive science. Local models allow causal power only to explicit representations, and the notion of an implicit representation is then usually restricted to what is logically implied by a system's explicit representations. For discussion see O'Brien 1993, and compare Hatfield 1991:95-96. Locke, relying on the animal spirits model of memory, caught the distinction by saying that "our Ideas are said to be in our Memories, when indeed, they are actually no where, but only there is an ability in the Mind, when it will, to revive them again": see Sutton 1998a:153-6, 167-9.

generalisation to new instances, and the distortion in memory produced by **interference** between traces due to superposition, since “the existing connections among the units will also influence the pattern constructed, thereby introducing the possibility of additions, omissions and distortions” (McClelland 1995:70). How, then, can a weird, discredited old theory based on the motions of imaginary fluids in any way implement this framework of distributed memory?

3. ANIMAL SPIRITS AND DISTRIBUTED MEMORY

Descartes' **Treatise on Man** (1972) was not fully translated into English until 1972, and only meagre extracts are included in the standard collection (Descartes 1985:99-106). It is a fable or thought experiment, describing a world of animated statues or zombies, dreaming machines which not only walk, breathe, sleep, reproduce, and digest but also have what are *to us* cognitive functions. Consistent neglect of Descartes' natural philosophy has obscured his complex accounts of sensation, imagination, memory, emotion, and dreaming; even sympathetic interpreters see his psychophysiological speculations as quaint, fantastical, and uncontrolled (Hatfield 1992:347-8). One historian berates Descartes for invoking non-linear neurophysiological feedback systems which are not quantifiable "by means of the mathematics he knows", and for violating his officially austere picture of matter in motion by placing so much importance on the notion of a pattern (Grosholz 1991:127-8). This somewhat puritanical lack of sympathy for the way Descartes smuggles "complexity in by the back door" (1991:72) is no accident, for it turns out that Grosholz's motivation is to attack modern reductionists like the Churchlands and Quine, whose views "bear the traces of Descartes' reductive method". For Grosholz, any search for mechanistic models should rule out in advance all "multifarious" and "prodigal" complexity at the psychological level (1991:81), and so any complexity found in Descartes' animal spirits theory must be deemed inconsistent with official Cartesian methodology. The following sketch is intended to demonstrate, in contrast, that there was (and is) no incompatibility between mechanism and holism, or reductionism and complexity (for a reply to similar criticisms see Paul Churchland 1989).

In their incessant motion through the pores of the brain, physical animal spirits transmit figures or patterns which are "imprinted in the internal part of the brain, which is the seat of Memory" (Descartes 1972:87). This is achieved through their bending or rearranging brain filaments so as to alter the intervals between pores through which the spirits will flow in future. The spirits "trace figures in these gaps, which correspond to those of the objects": on the repetition of a pattern of input, more enduring changes are made in the pores, so that patterns can be more easily formed again, in the absence of the specific stimulus (1972:87-88). The pattern of the pores, which constrains the patterned flow of spirits, is itself altered over time by the differing motions of the spirits. These patterned motions are not themselves stored, but merely "retained in such a way that" previous ideas can be recreated. Even if a particular input is only partially re-presented, recognition may still occur if the connected pores have been disposed so as to open together more easily (1972:89-90).

My account so far is uncontroversial: Hall notes that, for Descartes, "memory traces ... consist in residual patterns of openness among the interstices of the filamentous brain substance" (Descartes 1972:96, n.145). But later passages reveal that Descartes is thinking of the reconstructive process in remembering as depending on something very like superpositional storage. It "usually happens" that "several different figures are traced in [the] same region of the brain": thus "the spirits will acquire a combined impression of them all" (1972:96). So memories are motions, rather than separate atomic items. Every trace in a brain region affects any episode of processing, and so every memory is composite in the same way as every sensation carries the perceptual history of the organism. In subsequent correspondence, Descartes explains that "the folds of memory get in each other's way": "I do not think that there has to be a very large number of these folds to supply all the things we remember, because a single fold will do for all the things which resemble each other" (Descartes 1991:148, 151).

These cryptic remarks were developed in more detail by Descartes' follower Malebranche (on other “17th-century French connectionists” see Diamond 1969). Traces left in the brain by experience are "so well tied to one another" that they easily become "confused with each other": memory is only a facility retained in the brain fibres for being "bent anew in the same way" (Malebranche 1980:105-6, 141). Misassociation is natural on this model: it is "nearly impossible for so many traces ... to avoid becoming mixed up and bringing confusion into the ideas" (1980:141). Interference is a natural consequence of the Cartesian

model. English critics of Descartes focussed not on his vague remarks about a non-physical memory[5], but on the dangers of interference: Joseph Glanvill argued that if memories were motions as Descartes suggests, "one motion would cross and destroy another; all would be clashing and discord ... our memories will be stored with infinite variety of divers, yea contrary motions, which must needs interfere, thwart, and obstruct one another: and there would be nothing within us, but ataxy and disorder" (Glanvill 1970:39; see Sutton 1998a:129-148).

Even this briefest of sketches reveals the desired elements of a distributed model of memory. The reconstructive mechanism depends only on the relation between transient motions in the animal spirits and the enduring states of the brain pores: in other words, between patterns and transforming elements. Explicit representations are the fleeting patterns of spirit flow, and implicit representations are the dispositions left by experience in the folds of the brain. Many brain traces are "stored" in the same fold of the brain, and will thus interfere or mutually influence each other's nature on (re)construction. In the next section I show how this framework was linked with a wider dynamics of memory, body, and world: but first I must acknowledge one obvious objection to my reading of Descartes.

How, to put it bluntly, can a dualist like Descartes have had a naturalistic account of memory at all? Don't all mental functions belong to the incorporeal soul, being thus unavailable to animals and to the automata or dreaming machines who are the ostensible subjects of the **Treatise on Man**? The answer is that Descartes takes memory to be not a **mental** function at all, but a life function on a par with (though more complex than), nutritive and reproductive functions. There could be no science of the (rational) mind for Descartes: but there was a science of memory. Since we don't share his restriction of the mental to conscious rational thinking, we are at liberty to treat his theory of memory in its own terms. So it's not quite true that, for Descartes, "there can be no science of animal psychology" (Boden 1996:21): there may be no science of **reason**, but there are sciences of memory, perception, dreaming, and emotions.

This answer, however, will not satisfy, and the objection can be reformulated. Surely, without a soul, the only "memory" Descartes can allow will be reflex action, mere automatism, not part of a truly **cognitive** science of memory? Isn't it the case that, as Owen Flanagan says of the "impoverished" world of the "Cartesian automaton", "the complete system of wired-in reflex arcs exhausts its behavioral potential" (1991:3)? A full response to this reformulated objection would require an account of how even Cartesian beast-machines do have representations which go well beyond simple automatic responses to immediate stimuli (Gaukroger 1995:279-290; Sutton 1998a:74-81). But here it's enough to point out that Flanagan's point entirely neglects Descartes' corporeal **memory**. It's not just that responses to stimuli can be long delayed and integrated into more coherent patterns of behaviour, but that the picture of memory as spirits leaving traces in brain pores shows how an automaton's physiology changes over time. Automata with different histories marking their various brains and bodies will respond differently, and one automaton will respond differently at different times to the same stimulus after new experiences modify the spirits and pores in the folds of the brain. So it's a false dichotomy to restrict behaviour in Descartes' world to *either* simple automatism *or* incorporeally-mediated free action. In machines with the right microstructure, the past leaves specific traces in body and brain. The diverse causal factors involved in registering and integrating information include "previous brain episodes" and non-neural bodily events as well as current environmental input: "this is the model of an automaton, to be sure, but not one which operates by reflex" (Mackenzie 1989:174-5).

4. ANIMAL SPIRITS AND DYNAMICAL COGNITION

The model of memory embedded in early modern animal spirits theory fits van Gelder's description (1995:373) of a class of possible dynamical models, in which cognitive systems are "complexes of continuous, simultaneous, and mutually determining change": as he puts it,

> the cognitive system is not just the encapsulated brain; rather, since the nervous system, body, and environment are all constantly changing and simultaneously influencing each other, the true cognitive system is a single unified system embracing all three. ... [I]nteraction between the inner and the outer is best thought of as a matter of coupling, such that both sets of processes

[5] I discuss this underdeveloped "intellectual memory" in Sutton 1997, showing the restricted scope of Descartes' dualism.

continually influence each other's direction of change.

I seek briefly to explain how, within animal spirits theory, memory processes were coupled with, in turn, body, environment, and culture.

4.1 Animal Spirits and Embodied Memory

One important form of the "scaffolding" with which minds augment the resources of the lone brain is the use of bodily processes outside the brain for cognitive purposes. Just as the nervous system seems to develop "action loops" which operate by "'assuming' a specific backdrop of intrinsic bodily dynamics" (Clark 1997:36-45), so the brain utilizes other parts of the body for memory: Descartes notes that "a lute player ... has a part of his memory in his hands" (1991:146). Like Clark (1997:45,213-8), Descartes argues for an essential continuity between the employment of such assumed backdrops **within** the agent's body and the use of physical aids like writing and other external, technological storage. The body and the book, a safer place to keep stored items distinct, supplement weak natural memory in a manner necessary just because of the interference which is intrinsic to the superpositional format of internal storage.

But there is a more thorough integration of cognitive and bodily processes in animal spirits theory, to an extent modern (and postmodern) theorists of embodied cognition only dream about. The brain is always already reciprocally connected with the rest of the nervous system and the body, for the differences in animal spirit motions which determine cognitive processing are themselves determined not just by input from the world, but also by the states of other bodily systems: digestive, respiratory, and circulatory homeostasis is necessary for the reliable operation of the cognitive-informational system (A. Rorty 1992:377-380). Descartes retains the holism of earlier medical spirits theories, in which the blend of bodily fluids depends directly on the state of the blood and the regulation of temperature, and in which an individual's fluid balance is always specific, dependent not only on biological temperament but also on individual history. This is another way of saying that Cartesian automata are not narrow, specialized slaves of their hardwiring, but are at least as flexible and different as are their histories. For Descartes, "whatever can cause any change in the blood can also cause change in the spirits", and thus in brain processes: in a long passage, he examines both internal and external variables affecting the spirits, including food and digestion, respiration, climate, and the states of liver, gallbladder, spleen, and heart (1972:71-6).[6]

4.2 Context-dependence and Causal Holism

There are thus lines of direct and reciprocal causal dependence between memory processes in the brain, noncognitive bodily functions, and the world[7]. A better understanding of general Cartesian natural philosophy makes this less surprising than it might seem. Descartes did not kill off nature, stripping matter and the human body of activity, spirits, and complexity. His physiology, like his cosmology, is modelled on fluid dynamics: in the Cartesian plenum, everything affects everything else. Descartes' concern was not, in physics, to explain the isolated interactions of discrete atoms, how a body "behaves when not under constraint, but rather to account for what happens when a body moves from one system of constraints to another", such that "systems of constraint are constitutive" of the explananda (Gaukroger 1995:247-8; compare 84-9, 228-256). Just as Cartesian physics examines circulation, displacement, and endless motion, so Cartesian psychophysiology relies on various internal circulations at different explanatory levels. Like motions in the external world, memory motions are wholly context-dependent: the particular nature of any pattern of activation in the flow of spirits depends not just on the nature of traces previously left in the brain pores and on current input, but also on all the messy factors influencing the ongoing state of the spirits. And, again like motions in the external world, memory motions are causally holistic: all traces superpositionally stored in a brain fold are causally active in (re)constructing any one pattern of spirit flow.

4.3 Animal Spirits and Embedded Memory: cosmos and culture

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[6] A bewildering further Cartesian view on the embodied nature of cognition links reasoning and reproduction. Because animal spirits run by direct neural routes between brain and "the organs designed for generation", thinks Descartes, there is a mutually exclusive relation between scholarship and sex: as his follower La Forge puts it, "those who are given to debauching women are not very suitable for serious application to study" (see Sutton 1998a:208-211).

[7] So where some revisionary historians see animal spirits as closest to our neuropeptides, others take them as placemarkers for factors we take to be hormonal (Mackenzie 1989:175). This is one reason to resist the tempting view (held by Galvani himself) that animal spirits were not eliminated, but reduced to neural electricity: the spirits' domain was much wider.

The brain is always already reciprocally connected not just to the rest of the body, but also to the external world. If, as van Gelder and Port say, the "crucial point" of their dynamical approach is "that dynamical systems need not have anything corresponding to start or input states, or to final or output states, and state change need not be understood as discrete instantaneous mappings from one state to another" (1997:3), then animal spirits theory was a thoroughly dynamicist approach to cognition, world, and culture. Changes in diet, climate, sexual behaviour, stress and distress, sleeping patterns and a whole range of other factors directly influenced the fragile balance of internal fluids which drives brain processes. In the 17th century, only those who (unlike Descartes) *rejected* animal spirits and their influence by airs and places, like William Harvey, would "cut man off from his environment" (Frank 1980:40). And clearly, the influence of factors like climate, diet, and sex was in turn affected by the cognitive processes of the agents themselves, so that the kinds of "continuous reciprocal causation" (Clark 1997:163-6) in play here were always two-way.

In such a field of multiple simultaneous interactions in which "everything is simultaneously affecting everything else", the external parameters which affect the fast dynamics of internal state variables are themselves affected, at different time scales, by the changing state of the agent's cognitive processes themselves (van Gelder and Port 1995:23-5). There is no sense in which the factors influencing memory in Cartesian theory stop at the skin. As Malebranche states bluntly, the Cartesian view of the body implies that "we are to some extent joined to the entire universe": the forces of cosmos and culture traverse and permeate the innards by way of the animal spirits, so that everyone is joined "through his body to his relatives, friends, city, prince, country, clothes, house, land, horse, dog, to the entire earth, the sun, the stars, to all the heavens" (1980:342). It's hard to get more holistic than that.

5. CONCLUSION

This case study in historical cognitive science has addressed two claims made by radical proponents of the new dynamical approaches. I have queried the orthodox historical narrative, according to which embodied, situated cognition is a framework set up in opposition to Descartes' nasty individualism and its modern descendants. My historical account of early modern animal spirits neurophysiology revealed a recognizably distributed model of memory, in which explicit representations are patterns of spirit flow, and memory traces are changes left over the course of experience in the connections between pores of the brain. But this minor scholarly quibble with van Gelder, Clark, Wheeler and all over the interpretation of Descartes would be of no conceptual interest were it not for the fact that my alternative account of Descartes' theory of memory can be used to support and extend the second dynamicist claim: connectionists' stress on the cognitive importance of pattern-recreation does need to be supplemented by a real-time focus and by attention to the active roles of body and environment. Animal spirits theory does exhibit just the forms of continuous reciprocal causation between brain, body, and world which these theorists sees as the central promise of the new dynamicism in cognitive science: further, it allows easily for the embedding of brains in culture as well as in the physical world. The fact that animal spirits theory is an antiquated, baroque neurophysiological framework which postulates strange neural fluids which do not in fact exist is not, from this point of view, important; the fact that this outdated neural theory still supports these kinds of coupling between the inner and the outer simply confirms that distributed representation is a quite general abstract framework for learning and memory, which can be realized in quite different kinds of physical system, and that, further, distributed representation is easily compatible with the stress on scaffolding and the enviromental embedding of cognitive processes which dynamicists take to be so important.

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