The Subject at Rest: novel conceptualizations of self and brain from cognitive neuroscience's study of the 'resting state'

Felicity Callard and Daniel S Margulies

This is a pre-copy-editing, author-produced PDF of an article accepted for publication in *Subjectivity* following peer review. The definitive publisher-authenticated version

Callard, Felicity; Margulies, Daniel S, Subjectivity, Volume 4, Number 3, September 2011, pp. 227-257 is available online at:

http://www.palgrave-journals.com/sub/journal/v4/n3/abs/sub201111a.html

Abstract

The neuroscientific field of 'resting state' research has been described as heralding a paradigm shift in functional neuroimaging. As this new field has been central to the development of a cognitive neuroscientific theory of inner mental life, we here map and analyse its emergence and potential implications for conceptualizations of brain, self and subjectivity within and beyond the neurosciences. The paper traces how the 'the resting state' and 'default mode' became visible as objects of scientific enquiry through the yoking together of what were initially separate research endeavours addressing different neurophysiological and neuropsychological questions. In the process, 'rest' – as signifying the cessation of movement or labour – has been transformed: the brain, inner mental life – and potentially the self – are conceptualized by researchers in this field as perpetually productive and oriented towards the future.

Keywords: default mode, fMRI, neuroimaging, science and technology studies

1 Introduction

In 2009, the *Journal of Neuroscience* commemorated the 40th anniversary of the Society for Neuroscience by asking a number of prominent neuroscientists to reflect on the changes within the field over the past 40 years. Marcus Raichle announced in his paper that there had recently been nothing less than a paradigm shift in functional neuroimaging (Raichle, 2009). Raichle contrasted two perspectives on brain function, each of which, he contended, has had a long and complex history. According to one perspective, the brain 'is primarily reflexive, driven by the momentary demands of the environment'; according to the other, 'the brain's operations are mainly intrinsic involving the maintenance of information for interpreting, responding to and even predicting environmental demands' (p. 12729) . It is the former perspective that has characterized much of the corpus of experimental and theoretical research within the neurosciences. The latter perspective explicitly departs from most models of the brain that have characterized cognitive neuroscience. For much of the last century, this perspective was the neuroscientific underdog.

* * * * *

Over the course of the first decade of the twenty-first century, discussions regarding the brain – both within and especially beyond the neurosciences – have arguably been most preoccupied with and excited by three poles of research: (i) on *neuroplasticity* and *neurogenesis*, which describe the brain's capacity to reorganize itself by forming new neural connections throughout life, and the formation of new neurons in

the mature brain (Malabou, 2008; Rubin, 2009); (ii) a renewed focus on *emotion/affect* – as a remedy for the excision of these phenomena from earlier, overly cognitive models of brain and hence of self (see the research of Jaak Panksepp (1998), Antonio Damasio (Moss and Damasio, 2001; 1994; Damasio, 2000; Damasio, 2004), and Joseph LeDoux (1996; Phelps and LeDoux, 2005)); and (iii) on *mirror neurons* and, more generally, *social neuroscience* – the neural mechanisms of shared understanding and communications (for a review of mirror neuron research see: Rizzolatti and Craighero (2004), and for social neuroscience see: Lieberman (2007)). In complex articulation with these neuroscientific developments, the social sciences and humanities have been experiencing an efflorescence of theoretical and empirical research on the self and subjectivity that engages many of the same terms – for example, affect, empathy, and embodiment – that are currently common currency within the neurosciences. (Indeed, it is possible that the excitement surrounding neuroscientific research on mirror neurons and affect has, to date, been greater in fields *outside* of the neurosciences than within them.) Some of this research in the humanities and social sciences includes the creative use, translation and reworking of research findings, as well as more general concepts, from the neurosciences (e.g., Connolly (2002), Massumi (2002), Hansen (2004)). (For a consideration of the potential as well as the difficulties associated with these interdisciplinary engagements see (Cromby, 2007) and (Papoulias and Callard, 2010).) It is our contention that the brain – as it is being conceptualized and modelled by the neurosciences, as well as disseminated beyond them – is in the process of being reframed by a fourth potent arm of research, that on the brain's *resting state* and its *default mode* of function.

This emergent field is little more than a decade old. It comprises research on the brain in the absence of any explicit task, termed the 'resting state,' or 'default mode,' which has given rise to interest in the 'default mode network' (DMN), a set of brain regions that effectively underlie a novel core of cognitive function. In this paper, we map and analyse this emergent research field. Our intention is twofold. First, we trace the emergence of 'rest' and 'the resting state' as objects of scientific enquiry, and, in so doing, indicate how such scientific constructs challenge – as well as pay certain debts to – existing models of subject-environment interaction that are constituted within cognitive neuroscience. Second, we reflect on potential implications of such research for conceptualizations of subjectivity and of the self that coalesce in fields adjacent as well as distal to the neurosciences.

Findings from this new research field are beginning to circulate through various media channels. We write at a moment in which articles with such titles as 'The restless brain' (Jarrett, 2009), 'Devoted to distraction' (Glausiusz, 2009), 'Daydream achiever' (Lehrer, 2008), 'Perchance to daydream … and degenerate' (Valeo, 2008) and 'You are who you are by default' (Saey, 2009) are beginning to disseminate research concerning the resting state and the default mode network to various publics. It is precisely because processes of diffusion, dissemination and translation have only recently begun – and hence that the paths that such diffusion and translation will take are as yet underdetermined – that we consider it important to delineate some of the directions of travel, the consolidation of constructs, and the openings, as well as the potential perils, that such a field offers to those beyond its borders. The rapidity of dissemination and translation of research on mirror neurons is instructive in this regard. That the

experimental corpus on mirror neurons was both small and specific did not slow the speed with which mirror neurons were incorporated into hypotheses and models being developed in other neuroscientific fields, e.g. (Dapretto *et al*, 2006; Rizzolatti and Arbib, 1998; Williams *et al*, 2001). And it was certainly no block to the excitement with which 'mirror neurons' were greeted and set to work by diverse researchers within the social sciences and humanities, e.g. (Stafford, 2007; Orbach, 2009; Thrift, 2008).

We suggest that just as was the case with mirror neurons and neuroscientific research on affect, resting state/default mode network research is likely within the next few years to find a ready general audience and wide cultural currency both within and beyond academic circles. And, as with mirror neurons and affect, these movements of concepts and scientific findings are likely to entail a creative engagement with – and hence transformation of – the specific scientific premises and formulations exchanged by scientists within the field itself. It does not escape our notice that we are complicit in the wider dissemination of such research through the very writing of this paper. Our paper comprises a cross-disciplinary collaboration between a neuroscientist within the field of resting state functional magnetic resonance imaging (fMRI) research and a cultural theorist with expertise in the history and living present of psychiatry. Our positions within and to one side of the scientific field of resting state research allow us, we believe, to offer insights, cautionary as well as enthusiastic, regarding the potential that this field holds for reorienting some of the existing models through which subjectivity and brain-self-environment relations have been understood.

We are also aware that some of our conjectures regarding the ways in which resting state research findings might come to reorient conceptualizations of 'self' are

somewhat speculative. Nonetheless, we believe that this speculative wager will pay off if it encourages further critical reflection on the extent to which, and the means through which, neuroscience might play a part in moulding conceptualizations of the self. Nikolas Rose (Rose, 2007; Rose, 1998) and Emily Martin (Martin, 2007), amongst others, have demonstrated intricate and two-way relationships between (neuro)scientific constructs relating to the self and conceptualizations of the self that circulate in other domains. We consider, in the specific context of resting state research, how such relationships are in the very process of being forged. We leave to our readers the question of whether our analyses adumbrate or, rather, actively intervene in this process.

2 Revolutions of a restless neuroscience

The claims now being made on behalf of resting state research – as Raichle's announcement of a paradigm shift (Raichle, 2009) makes clear – wish to underline its historically revolutionary status.[1] But, notably, the claims for newness and the excitement surrounding this field are conjoined with an emphasis on its revivification of a hitherto submerged perspective on brain function. Indeed, Raichle, in proclaiming the impending paradigm shift, dwells on how 'surprising discoveries' (p. 12729) in imaging research have opened up a new chapter in what has actually been an historically long-standing interest in exploring the behavioural relevance of intrinsic brain activity. He leans, here, on the genealogy presented by the eminent neuroscientist and physiologist Rodolfo Llinás (2001). Llinás contrasts the work of William James and the famous neurophysiologist Charles Sherrington with that of Sherrington's disciple, T. Graham Brown. James and Sherrington conceptualized the central nervous system as

fundamentally reflexive, in which ‘the brain is essentially a complex input/output system driven by the momentary demands of the environment’ (Llinás, 2001, p. 6) . In contrast, Brown argued that the spinal cord ought not to be understood as reflexological, and indeed that movement could be intrinsically generated in the absence of sensory input:

> It is therefore possible to look upon the neuraxial unit as the efferent neurone and not as the reflex arc, and *to regard as the primitive activity not the reflex but that rhythmic phenomenon* of which there still remain examples in the acts of progression and re- spiration. (Brown, 1914, p. 45) [italics added]

Brown’s prime focus was on the rhythmic and intrinsic organization of gait: he argued that his research demonstrated that the conditioning of rhythmic activity is largely self-generated, such that sensory input modulates but does not determine it. He thus refocuses our conceptual lenses away from the phenomenon of the reflex arc and towards that of rhythmic intrinsic organization. Llinás argues that Brown’s insights on spinal cord function may be extrapolated to the operations of the brainstem and areas of higher brain function. On this view of the brain, sensory input ‘modulates rather than informs’ (Llinás, 2001, p. 7) intrinsic nervous system function. Such a view runs counter to many theoretical frameworks employed by various disciplines in the course of the twentieth century to understand and model the human brain and cognition, not least behaviourism, orthodox cognitive psychology, and later cognitive neuroscience. Indeed, such a view entails a potential reconfiguring of the articulation between brain, self and environment –

or between internal and external world – from the one familiar to us from cognitive science.

Resting state research, in explicitly allying itself with Brown over Sherrington, positions itself on one side of a long running duel, one whose axis centres on the opposition between the reflexive and the intrinsic. The field is also, of course, indebted to other scientific concepts, models and approaches. A genealogical approach to the problematics engaged by 'resting state' research would need to contend with Bichat's formulations regarding life as a collection of processes that resist death; with research on homeostasis in the early twentieth century by Walter Cannon and others; and with the cybernetic models of homeostasis that were such a fertile resource for cognitive science and systems theory.[2]

But how did rest and 'the resting state' emerge as topics of explicit scientific enquiry within neuroscience? In this section, we provide a brief history (see also Buckner *et al*, 2008), paying particular attention to some of the manoeuvring of different neuroscientific sub-disciplines, and to the moments at which initially distinct constructs and terms coalesced. Of particular interest are the two distinct paths – with distinct methodologies, techniques and fields of expertise – out of which the field as we know it today has been constituted: cognitive psychology and neurophysiology. We contend that, over the course of the last decade, the terminology employed within this field has been transformed – in the process moving to vocabulary that is less contentious, arguably more tightly bounded, and primed for a neuroscientific framing of inner mental life.

2.1 History of resting state research: Lineage 1 – 'default mode'

For cognitive psychologists and neuroscientists, a cross with arms of equal length (Figure 1) signifies a classic condition for the control state during an experiment. It is the state of rest, a neutral state, baseline, the moment of 'crosshair fixation'. For cognitive neuroscience, this state has long been on the opposing side of the cognition it aimed to study.

***** INSERT FIGURE 1 ABOUT HERE *****

Most categories of study in cognitive neuroscience emerged from a century-old lineage of experimental psychology. The traditional approach in neuroimaging studies, both in positron emission tomography (PET) and continuing with fMRI, was the contrast of a specific state (e.g. visual stimulus, sustained attention, memory retrieval) with a state in which subjects were simply asked to rest. Depending on the experimental condition, this 'resting-state' could be with eyes closed, eyes open, or fixation on a crosshair. Rest was implicitly considered a cognitive baseline against which task demands elevated brain activity in function-specific regions (Figure 2).

***** INSERT FIGURE 2 ABOUT HERE *****

Gordon Shulman and colleagues at Washington University in St. Louis (one of the foremost institutions in the field of cognitive neuroscience) systematically noted some regions of the brain consistently appeared to *decrease* in activity across a variety of task

conditions. In 1997, they published their findings in the *Journal of Cognitive Neuroscience*, showing in a meta-analysis of nine different PET studies that a distribution of regions including the medial prefrontal, posterior cingulate / precuneus, and lateral parietal cortex were more active when subjects were resting (Figure 3) (Shulman *et al*, 1997). This paper also argued that while a passive control condition in the experimental design might for some appear to be 'too underspecified' to act as a reliable control, their analysis indicated that 'passive conditions' across a wide variety of experiments produced a 'consistent set of blood flow changes' and could thereby serve as a control state (p. 657). Notably, Shulman and colleagues also ruminated on the blood flow decreases caused by ongoing processes in the passive mental state, suggesting the possibility of unconstrained verbal thought processes, monitoring of the external environment, and monitoring of the body image. (Such constructs would, notably, return in later attempts to theorize what is happening cognitively when the brain is 'at rest'.) They explicitly considered that processes in the 'passive condition' might have an 'antithetical relationship' to active task processes (as sleep is antithetical to an alert state, a 'general exploratory/monitoring state' might be antithetical to a task-focused state). This shift – which we shall term 'The Flipping of Contrasts' – was very simple analytically (subtracting – or 'contrasting' – the task condition from rest, rather than the standard subtraction of the resting condition from task), but it presented cognitive neuroscience with the substantial conceptual problem of how to make sense of the data. If a large swath of cortex is more active during a state of rest, what is happening *psychologically* during rest that is driving this increased activity?

***** INSERT FIGURE 3 ABOUT HERE *****

The term ‘default mode’ entered the cognitive neuroscience vocabulary to describe the functional state of rest, in the contemporary sense, with Marcus Raichle’s and colleagues’ publication of three papers in 2001 (Gusnard *et al*, 2001; Gusnard and Raichle, 2001; Raichle *et al*, 2001).[3] Many of these task-induced decreases in brain activity appeared to be ‘largely task independent, varying little in their location across a wide range of tasks’. Such consistency made them consider whether there might be ‘an organized mode of brain function that is present as a baseline or default state and is suspended during specific goal-directed behaviours’ (Gusnard *et al*, 2001, p. 4259). Through a semiotic linking of functional neuroanatomy to the regions found to be more active during rest, several hypotheses were proposed regarding the psychological content of the resting state. Debra Gusnard and colleagues postulated that the observed medial prefrontal cortex activity reflected the predominance of self-referential mental activity (also observed to implicate the medial prefrontal cortex) that occurs in the absence of environmental demands. They furthermore tentatively proposed that such activity was involved in the ‘processing of such representations that *embody aspects of self*’ (Gusnard *et al*, 2001, p. 4263) [italics added], and linked such processing to the concept of the autobiographical self proposed by Damasio (Damasio, 2000) and that of the narrative self proposed by the philosopher Shaun Gallagher (Gallagher, 2000). Gusnard and Raichle’s review in *Nature Reviews Neuroscience* (Gusnard and Raichle, 2001) elaborated their theory of a default mode of brain function based in neurophysiological, as well as psychological questions, thus invigorating long-neglected research questions regarding

internally-driven mental states. These three papers were central – and not solely in terms of their inauguration of a new research field. For they indicated that one 'useful way' to address the 'important concept' of the self was 'to further explore the nature of default state activity' (Gusnard *et al*, 2001, p. 4263): in so doing, these authors established an enduring and intimate tie between the resting state and investigation of the neural architecture of the self.

It would take us too far afield from the central concerns of this paper adequately to address the numerous research findings and debates regarding the default mode since 2001. What follows is a schematic outline of some themes that are most critical to the arguments of this paper, along with brief indications of the methods employed.

(i) *Goal-directedness*: While activity during the default mode was initially set in opposition to 'goal-directed behaviour' (Shulman *et al*, 1997), it was subsequently reconceptualised as involved in long-term, goal-directed planning, as numerous studies hypothesized its role in prospection, or future-oriented thinking (Spreng *et al*, 2009). While the task paradigms for interrogating these cognitive faculties did not differ from traditional cognitive neuroscience methodologies, it is the focus on unravelling the function of regions within the default mode network that was novel.

(ii) *Quantification of stimulus-independent thoughts and the invigoration of research on mind-wandering*: More recently, we have witnessed the coalescence of research on the default mode network with other cross-disciplinary areas of research. Most notably, previously dispersed research on stimulus-independent thoughts, task-unrelated thoughts and 'zone outs' has been gathered together under the umbrella term of 'mind-wandering' (Smallwood *et al*, 2008; Mason *et al*, 2007; Gilbert *et al*, 2007;

Christoff *et al*, 2009; Smallwood and Schooler, 2006). Through such research, phenomena such as mind-wandering, which have previously been marginal to the theorisations of brain and self undertaken by cognitive science, have been installed as far more fundamental. Mason and colleagues' study in *Science*, for example, contended that mind-wandering constitutes 'a psychological baseline that emerges when the brain is otherwise unoccupied' and that is underpinned by activity in a default network of cortical regions (Mason *et al*, 2007, p. 394). (That the dissemination of such research into the public sphere is undertaken via the use of such statements as 'Daydreaming seems to be the default setting of the human mind' (Fox, 2007) underlines how such research is effecting a shift away from a model of the self oriented towards external goals so beloved by orthodox cognitive psychology.)

In terms of methods, the study by Mason and colleagues, which aimed to address 'the relationship between the default network and mind-wandering' (Mason *et al*, 2007, p. 394), measured the frequency of stimulus independent thoughts during auditory and visuospatial working memory tasks, then correlated the scores with the level of task-induced deactivation. Although the task remained the same, the analysis now focused on the frequency of lapsed attention, rather than moment-to-moment attention. In other words, just as with the initial 'Flipping of the Contrasts', such studies required no fundamental methodological or technological *breakthroughs*, but rather a refocusing of scientists' analytical gaze on what was hitherto regarded as unworthy of specific attention.

(iii) *Self-related processing, episodic memory, social cognition and sense of agency*: Topics of inner rumination, reflection, motivation have been subsumed under the

heading of default mode function, using findings from task-based studies to support the specialized roles of the implicated regions (Spreng *et al*, 2009; Goldberg *et al*, 2008; Schilbach *et al*, 2008; Moll *et al*, 2007). Much support has been drawn from the rationale that the content of mind-wandering is composed of episodic memory, prospection, and the consideration of social relationships. Given the diversity of roles attributed to the regions of the default mode network (DMN), more recent work has attempted a network-based rendition of the modular theory of brain function (which postulates that each functional area of the brain has a singular role), thus subdividing the DMN in order to accommodate the diversity of ascribed functions (Andrews-Hanna *et al*, 2010).

Much of this empirical and conceptual research on the default mode, it should be emphasized, has drawn extensively on findings and formulations from a range of other sub-domains of cognitive neuroscience. Regardless, however, of the cohesiveness of the cognitive constructs as they were fitted within the emergent DMN model, or of the precise spatial distribution of the responsible network, a cognitive neuroscience of inner experience was taking form through linking the functional roles of brain regions that are more activated during the state of rest with the psychology of unconstrained mental activity.

2.2 History of resting state research: Lineage II – spontaneous brain activity

We have thus far focused on cognitive neuropsychology as it established the foundations and terminology for studying the brain's function in the *psychological* state of rest. However, interest in 'resting' brain activity, albeit of a different sort, preceded Shulman and colleagues' 'Flipping of the Contrasts' in 1997. Bharat Biswal and other

physicist colleagues, who were then based at the University of Wisconsin in Milwaukee, were working under the guidance of James Hyde (a pioneer in the development of fMRI technologies). Rather than asking the *neuropsychological* question posed by Shulman and colleagues, they posed a parallel question about the role of the spontaneous activity that was discarded as noise in analytic models.[4] Instead of inquiring about a functionally relevant psychological baseline condition, Biswal and colleagues explored the possibility that baseline physiological activity might be functionally significant and reflect neural organization.

That spontaneous neurophysiological activity was functionally relevant was not a new idea,[5] but it had fallen behind the hypothesis of the input-output model driving behavioural psychology. If the brain were instead primarily driven by the requirement to maintain its own dynamics, with environmental input only modulating, rather than driving its function, the spontaneous endogenous dynamics would be meaningful and not simply unconstrained noise. Biswal and colleagues addressed this question in 1995 with a remarkably simple paradigm (Biswal *et al*, 1995). They began with a standard finger-tapping task in a 'boxcar' design (see Figure 2), in which the task – or 'on' – condition (here, 'finger-tapping') occurs in several experimental 'blocks', each of which is separated by a period of non-task, 'off' time. Expectedly, the motor cortex was activated more during tapping than during the resting-condition. Their innovation was to then take data collected from the same subjects during a rest-only condition and to analyse the correlation of the spontaneous fluctuations occurring between a small portion of selected motor cortex and the rest of the brain. They found that the same areas of motor cortex activated during the tapping-task were spontaneously correlated at rest (Figure 4). The

notion that spatially remote areas of the brain could be spontaneously correlated, and that such a relationship served as a measure function-based connectivity, was not new (Friston *et al*, 1993). However, the observation that 'functional connectivity' during a resting-state contained similar neural organization as task-evoked patterns of activity was indeed novel. Here, the title of their seminal article: 'Functional connectivity in the motor cortex of resting human brain using echo-planar MRI,' reflects the union of fields that was to follow almost a decade later. Thus, it appeared that the brain was functionally coordinated into spatially consistent areas *even in a task-independent state of rest*.

***** INSERT FIGURE 4 SOMEWHERE NEAR HERE *****

From an analytic perspective the transition was easy, although it took almost a decade to overcome the field's bias. The only difference from task-based data analysis was the derivation of the statistical model: rather than hypothesize the fMRI response from an environmental stimulus and test which areas of the brain may be correlated, the data themselves provide the model. The data processing tools remain largely the same, but the statistical model shifts from externally to internally defined. The theoretical shift, on the other hand, is from localization of functional areas to delineating connectivity and large-scale functional networks (Van Dijk *et al*, 2010; Bullmore and Sporns, 2009). Numerous publications have used functional connectivity analysis of resting state fMRI data to map neuroanatomical systems (Margulies *et al*, 2007; Di Martino *et al*, 2008; Roy *et al*, 2009; Krienen and Buckner, 2009; Vincent *et al*, 2008; Smith *et al*, 2009), differentiate patient groups (Greicius, 2008; Fornito and Bullmore, 2010; Seeley *et al*, 2009; Fox and Greicius, 2010), and map developmental changes (Kelly *et al*, 2009; Fair

et al, 2009; Fransson *et al*, 2007). The approach has been used to investigate functional brain differences in groups and topics that would otherwise not be capable of task participation, such as other species (Margulies *et al*, 2009; Vincent *et al*, 2007; Vincent *et al*, 2010; Biswal and Kannurpatti, 2009), and different levels of consciousness in humans (Boly *et al*, 2008; Horovitz *et al*, 2008; Fukunaga *et al*, 2006). Since all that is required during data collection is that the participant remains motionless in the scanner environment, resting state fMRI data has also opened the possibility of data-sharing across institutions on an unprecedented scale (Biswal *et al*, 2010). With the recent publication of Biswal and colleagues' multi-site study, consisting of over 1000 datasets (in a field which usually does not exceed a few dozen per study), the field of functional imaging seems at the cusp of large-scale population studies, and shares the excitement and research aspirations with which genetics entered the last decade.

2.3 Consolidating the 'resting-state' field of research

The links between the field of dynamic physiological properties in the resting human brain with the field of dynamic psychological properties in the resting human brain were not as obvious as they perhaps might now seem. Biswal's findings were not initially popular within the imaging community, and cognitive neuroscience did not know how to integrate Raichle's work. One may conjecture that the two groups were either unaware of (or unaware of how to link) each other's work, as no cross citations exist prior to 2003.[6]

A young researcher named Michael Greicius who was working in the laboratory of Vinod Menon at Stanford University made the connection. His article, published in

Proceedings of the National Academy of Sciences and edited by Raichle, was entitled 'Functional connectivity in the resting brain [*note the Biswal reference*]: a network analysis of the default mode hypothesis [*note the Raichle reference*]' (Greicius *et al*, 2003). At the core of the study was the resting state functional connectivity technique developed by Biswal: Greicius and colleagues found that the regions more activated during the baseline state were also intrinsically correlated at rest. The unification of these two fields, one neuropsychological, the other physiological, and both essentially a break with the dominant model of input-output brain function, marked the beginning of what we now know as 'resting-state fMRI'. It was here that Greicius and colleagues coined the functional-anatomical term that has become almost synonymous with the name of the field itself: the 'default-mode *network*'. It was this network, they argued, that 'account[ed], in large part, for the phenomenon of task-related decreases in brain activity' (Greicius *et al*, 2003, p. 256). The blending of the two fields is most exemplified by a statement by Raichle and Snyder from a response paper published in 2007 in the journal *NeuroImage*: 'The important distinction is not between "rest" and "task" but rather between intrinsic and evoked activity' (Raichle and Snyder, 2007, p. 1088).

The yoking of the physiological and the psychological approaches to one another has meant that, even as the 'resting state' research field now appears to be a unitary one, it retains within it distinct theoretical foundations and terminologies. This theoretical fecundity has been advantageous in terms of sparking wide-ranging empirical research as well as giving extra impetus to model building. But it has also meant that the 'resting state' and the mapping of the cognitive function of the default mode network are frequently conflated. On the one side is interest in how the *brain* functions and organizes

through spontaneous, intrinsically-driven activity, while on the other side research is primarily invested in characterizing the *psychological state* (and corresponding brain state) during the absence of specific environmentally-driven task demands. By uniting both fields under one banner, they flank each other to criticism directed at either side, and offer a wider landscape of interpretation – in many cases due to the use of loose terminology and interpretation. The creative semiotic terrain produced through the mixing of these terminologies has aided and will, we suggest, continue to aid the transmission of this research into other disciplinary arenas and into the public sphere.

2.4 Resisting rest

Raichle and Snyder's insistence that the important distinction was not between rest and task, but rather between intrinsic and evoked activity marked a distinct shift from the call-to-research of Raichle and colleagues' 2001 articles. Notably, Raichle and Snyder's formulation was not self-standing, but rather appeared as a central element in their defence of resting state research against a stringent critique launched by two researchers, Alexa Morcom and Paul Fletcher, who were attached to a dominant hub of cognitive neuroimaging, the Brain Mapping Unit at the University of Cambridge. Morcom and Fletcher's paper (2007) – provocatively entitled 'Does the brain have a baseline? Why we should be resisting a rest' – marked the first explicit challenge to the maturing field of resting state research.[7] The paper did not dispute Raichle and colleagues' characterization of the resting state as 'active', but rather attempted to undermine 'its claim to a *special* status' [italics added] (p. 1080). Indeed, the paper used the adjective 'special' a number of times – and each in the context of clarifying Morcom and Fletcher's central argument

that acknowledgement of the resting state in no way entailed a need to refocus attention away from the task-based manipulations long familiar to cognitive neuroscience. On Morcom and Fletcher's account, in short, a focus on the intrinsic activity of the resting brain carried the danger of 'imply[ing] that it has *somewhat mysterious functions* not amenable to study using "tasks"' [italics added] (p. 1078). Since, for them, task-based paradigms were essential for any progress to be made vis-à-vis how the brain supports cognition, and since 'the cognitive nature of rest is at present almost entirely a matter of speculation' (p. 1079), the implications were clear: the cognitive characteristics of the resting state required investigation through the use of appropriate tasks. '[M]odern systems neuroscience' must, after all, they argued, 'be sophisticated in cognitive, as well as physiological and network terms' (p.1081). Morcom continued in the same vein in subsequent interviews, critiquing the DMN theory as 'very unpsychological' (Jarrett, 2009, p. 838); she was joined by Sam Gilbert, a colleague at another world-leading cognitive neuroscience department, that of University College London (UCL), who reiterated that 'The DMN literature reflects ... a decognitivisation of cognitive neuroscience' (Jarrett, 2009, p. 838).

What is striking about Morcom and Fletcher's critique is their need to downplay any disturbance that the constructs of 'the resting state' and the DMN might be bringing about within the established field of cognitive neuroscience. The frequency of their use of the word 'special'; their refusal to bestow upon the resting state 'a privileged status' in the study of human behaviour; their antipathy towards granting the resting brain 'somewhat mysterious functions' that operate outside of the fold of task-based paradigms: each of these rhetorical moves emphasizes the authors' conviction that it is

cognition – and its exploration via the use of highly controlled, task-based designs – that must remain at the heart of the neuroscientific exploration of the brain. Their paper, then, points to an ongoing and pivotal debate surrounding the resting state field: the extent to which its model of brain (and self) endorses orthodox cognitive conceptions and the extent to which it departs from them.

3 Interlude: 'rest' and 'default'

Before it is possible to begin to formulate a preliminary response to this question, it is necessary to stand back from the intricacies of the manoeuvres we have been tracking in order to reflect on the wider semantic terrain inhabited by this emergent scientific field. What, in short, do the terms 'rest' and 'default' denote? Both are complex and polysemic. This adds to the difficulty of discerning if and how the resting state research field fits within, or moves beyond, the orthodox cognitivism of much of the wider neuroscientific terrain. It also adds to the likelihood that there will be a creative multiplication of meanings and connotations as findings and formulations are disseminated beyond academic circles.

3.1 'Default'

The current meaning of default – a condition that obtains in the absence of active intervention – is etymologically very recent. The *Oxford English Dictionary* traces its use to 1966: to define a preselected option adopted by a computer when no alternative is specified by the user or programmer.[8] Here, the 'default' is something that is specifically programmed into a system, rather than being immanent to it. But the artificiality of the system disappears once the term travels beyond the realm of programming, such that the 'default' connotes the

neutral state of the system – how it might act in the absence of interventions/stimuli. Such a 'neutral state' easily slides towards connoting the core, functional state of the system, and from there, to what the system most 'naturally' returns to.

For anyone who is at all familiar with computers, a 'default' setting of the brain is therefore likely to be an easy concept to grasp. There are two points to make here vis-à-vis the close relationship that the term 'default' establishes between the brain and the computer. One is the straightforward one that the dissemination of resting state/default mode research is likely to be rendered easier by the fact that the adjective 'default' is part of lay terminology – at least for those familiar with computers. The second is the more interesting: over the last quarter century, computers have had an enormous impact on our understandings and conceptualizations of both the brain ('the brain as computer') and the self (e.g. Turkle, 1995). In other words, any influence that resting state research has on everyday conceptualizations of the brain and self is likely to be carried on the back of the already powerful influences that the computer and computing have on such conceptualizations.[9]

3.2 'Rest'

This term has, of course, a rich philosophical, anthropological, religious and sociological – as well as biological and physiological – history. It is therefore metaphorically and metonymically very rich, a characteristic that has been exploited to the full by scientists, external commentators and critics when discussing research on the resting state. (Those of us who are social scientists ought not to imagine that the term 'rest' has lain uninterrogated by those within the field. Indeed, resting state researchers – along with their interlocutors – have done much conceptual ground-clearing vis-à-vis the

difficulties of the term.) The etymology of 'rest', as described by the *Oxford English Dictionary*, indicates that uses of the word have included: a natural repose or relief from activity; the intermission of labour or exertion (hence the Sabbath as the day of rest); freedom from distress or trouble; quiet or tranquillity of mind; an interval of silence or a pause (in music); the cessation of motion; and continuance in the same position or place. In this sense, rest can variously be regarded as the opposite of: activity, busyness, labour, movement, restlessness and agitation. Hints of several of these meanings are to be found within the scientific and popular literature on the resting state and the DMN. And, as we shall later discuss, this literature is engaged in a substantial reconfiguration of several of the term's uses.

4 Paradigms contrasted: the subject (not) at rest

The previous sections have attempted to depict the complexity of the field of transformations produced through the emergence of the resting state research field and the proclamation of a new paradigm in functional neuroimaging. These transformations have been not only methodological, but have been accompanied by disciplinary disturbances as well as ontological and epistemological shifts in how the brain is conceptualized and scientifically interrogated.

In the remainder of the paper, we analyse in greater detail some of the potential implications of these transformations for models of brain, self and subjectivity. We start with a schematic depiction of the 'old' and the 'new paradigm' (see Table 1). The cells in each column are synthesized from representations that those within the 'old' and 'new' categories have used to characterize their own and the other paradigm; portrayals of these

paradigms in popular literature; and our own analyses of the typifying features of each. It is easy to critique such a bifurcation. But while the table provides an overly schematic division of what is in actuality a much more heterogeneous field, we nonetheless believe that it is helpful to articulate some of these differences starkly so as to gain greater analytical purchase on what might be at stake in Raichle's announcement of a 'paradigm shift' in functional brain imaging. It is, nonetheless, important to keep in mind that the shifts effected by the resting state/DMN field are part of a much larger and heterogeneous series of changes in how neuroscientists are conceptualizing the brain and the self. In other words, we should not be misled into believing that the 'new paradigm' has arisen through findings, constructs and methods developed solely by resting state/default mode researchers.

* * * * * INSERT TABLE 1 ABOUT HERE * * * * *

The final third of Table 1 indicates how the methods and objects of resting state research specified in the second third of the table potentially catalyse a new model of brain and self within cognitive neuroscience. The intrigue with and focus on non-observable and unconstrained mental activity, for example, contributes to the emergence of an account of the self grounded as much through mind-wandering and introspection as through deliberate, goal-focused activity; the focus on the rhythm of the intrinsic and spontaneous dynamics of the brain contributes to the emergence of an account of the self specified through and anchored by those dynamics rather than through her responses to the environment and the exteroceptive stimuli that impinge upon her. And the shift in focus to slow frequencies on a multi-second scale, much closer to the rhythms of

phenomenal perception, is a fortuitous by-product of using fMRI with its slow temporal resolution to explore psychological and physiological dynamics (rather than electroencephalography, which traditionally only addresses fluctuations faster than one second – much closer to a time-scale of interest to neurons).

As resting state and DMN findings begin to be disseminated, it is possible to discern already how they are being used to ground particular visions both of the self and of the intimate tie between brain and self. The neuroscientists Susan Whitfield-Gabrieli and John Gabrieli, for example, in an online article for *Scientific American* about the default mode have suggested that the:

> exciting discoveries about the resting human brain raise the question of whether we are gaining the novel capacity to measure quantitatively our most intimate and unique inner selves. Are you most "you" when you're racing through work? Or when you're simply sitting in a chair, mind adrift, just being? (Whitfield-Gabrieli and Gabrieli, 2010)

Raichle, himself, in a recent cover feature for the *Scientific American*, writes:

> The brain's default mode of function serves as a master organizer of its dark energy. Over time neural dark energy may ultimately be revealed as the very essence of what makes us tick. (Raichle, 2010, p. 49)

If, as Nikolas Rose has argued, the spaces of contemporary biomedicine and biopolitics are opening up 'new ideas of what human beings are' (Rose, 2007, p. 6), then there appear already to be indications that the resting state and the DMN might be installed as a new foundation for the self. In the two quotations above, it is the subject 'at rest' that – by dint of her default mode brain activity – potentially holds the key to subjectivity *tout court*. We can see the ease with which the analytical distance between resting state data, models of DMN activity, and claims about the nature of subjectivity can be flattened.

The explosive growth of resting state research has, then, started to make its mark felt beyond the laboratory. In the process, 'rest' has been rewritten to comprise various active, internal psychological states. The past century of experimental psychology was built upon those aspects of cognition that it could modulate and measure externally. The emergence of the concept of a default mode of neural and psychological activity has impinged on the inner territory of the subject, and, in the process, has contributed to renewed interest in developing experimental paradigms that would investigate this territory. In little more than a decade, the 'task induced deactivations' noticed by Shulman and colleagues have moved from being a complete mystery, to being configured as a coherent network that has been described in *ScienceNews* as 'one of the hardest-working systems in the brain' – 'despite its laid-back name' (Saey, 2009, p. 16). Rest – to follow Raichle in his frequent use of a quotation from Seneca – has in this formulation certainly become 'far from restful'.[10]

We wish to comment on one particularly noticeable consequence of this reconfiguration of 'rest', not least because it significantly reorients some of the previous assumptions and guiding models used within the humanities and social sciences to

describe and conceptualize a self who is not engaged in deliberate and purposive activity. It is our contention that the reconfiguration of rest has helped to consolidate a model of the resting brain as a matrix that is constituted as perpetually productive, as intrinsically creative, and as thrown towards the future. While many of the research findings that ground such a model in fact existed prior to the emergence of the default mode/resting state literature, they arguably required the compelling image of the brain as exhibiting 'unrest at rest' in order to circulate more widely.

Most notably, the increased focus on the importance of mind-wandering and daydreaming in no way gainsays the brain's industriousness. Buckner and colleagues, for example, in describing resting state activity, speculate that: 'Rather than let the moments pass with idle brain activity, we capitalize on them to consolidate past experience in ways that are adaptive for our future needs' (Buckner *et al*, 2008, p. 31). Raichle and Snyder make no bones about the fact that, for them, study of the default mode of the brain enhances investigation of 'the real reason we have a brain'[11]: 'not to reminisce about the past nor react in the moment but, rather, to envision the future' (Raichle and Snyder, 2007, p. 1089). The brain, on Raichle's account, functions as a kind of 'Bayesian inference engine' through which it is able to generate predictions of the future, and to link these predictions with its reflections on the past. Such abilities are, moreover, central to 'the development of unique human attributes such as imagination and creativity' (Raichle, 2006, p. 1250). Unsurprisingly, then, as this research travels through popular science publications – and thence more broadly to a number of publics – the use of tropes of productivity to characterize states of only apparent idleness, multiply. As Saey puts it: 'It may be off when you're on, but the brain network behind daydreams and a sense of

self is no slacker' (Saey, 2009, p. 16). (It is notable that resting state research employs tropes of industriousness and the desire for 'no-backlog' that are of a piece with today's discourses regarding neo-liberalism. There remains much to be explored vis-à-vis how to understand and interpret the often unacknowledged isomorphism between models of the brain and models of socio-economic organization (Martin, 2007; Malabou, 2008).)

The model of mind-wandering as industriousness is in distinct contrast to those accounts of day-dreaming and mind wandering that dominated late nineteenth and twentieth-century philosophy and social theory. For Freud, for example, the key conceptual term in his famous essay 'Writers and day-dreaming' is *play*; this is 'serious play', certainly, but play nonetheless (Freud, 1908). Freud's mind is one in which 'hardly anything is harder for a man than to give up a pleasure which he has once experienced'. Indeed, the subject does not give something up but exchanges one thing for another, such that as the child grows, he 'builds castles in the air' rather than castles made out of bricks. The contrast between Freud's formulation (in which subjectivity is weighted by the pull of the past) and that of Raichle and Buckner (with the subject's adaptive orientation to the future, even – perhaps especially – in its consolidation of memory) could not be more marked.[12]

The gap that separates some of those philosophical interrogations of memory and subjectivity so central to modernity from current research findings associated with the default mode can also be discerned through the repositioning of that most redolent of symbolic objects: Proust's madeleine. Visual neuroscientist Moshe Bar, in two articles that address the 'proactive brain' (Bar, 2007; Bar, 2009), elaborates how such a brain when 'not engaged in some demanding and all-consuming task' (Bar, 2009, p. 1238) –

continuously generates predictions by ‘proactively linking’ incoming features to existing, familiar information. Bar argues that there is a ‘striking overlap’ between the cortical network mediating contextual associative processing and the default network. Such a model means that for Bar there is in fact a ‘payoff’ for the brain’s investment of energy in ‘mind wandering, fantasizing and revisiting (and modifying) existing memories’ (Bar, 2009, p. 1239): what appear to be random thoughts and ‘aimless’ mental simulations create memories. Crucially, he explicitly contrasts his model, in which acquired memory is important for future survival and adaptation with the environment, with one of the key loci for conceptualizations of memory in modernity:

> Consequently, the cardinal purpose of memory starts to seem less for leisured reminiscing, as in the famous example of Proust’s Madeleine, and more as a knowledge-base that guides our lives in an increasingly more informed manner. (Bar, 2007, p. 286)

Let us set to one side Bar's unique characterization of a moment in *Swann's Way* in which Proust narrates the surfacing of memory as peremptory and compelled as a moment of 'leisured reminiscence'. Instead, note how the 'pay off' that Bar reads into the brain's investment in mind-wandering and fantasizing is one that points to a model of mental activity in which the potential for the designless, footloose and aimless is converted into the purposive, generative and aimful.

The reconceptualisation of rest is also contributing to the reframing of older, analytical frameworks and constructs that functioned in a binary manner. One way in

which William James, for example, divided the field of consciousness was to oppose attention to the state of absentmindedness conjured up by the French term *distraction* and the German *Zerstreutheit*. For James, it was the abolition of the state of distraction[13] that signalled the awakening of the attention (James, 1890, pp. 404–405). In contrast, the model of attention being developed in the DMN literature reformulates absentmindedness or mind-wandering as a form of introspective attention. Here, network brain activity 'at rest' is mapped on to the psychological category of attention, such that attention's opposite no longer exists. Instead, we have two types of attention – the intro- and the extrospective. The neuroscientist Peter Fransson, in a similar manoeuvre, argues that activity during the default mode disallows the possibility that one might, metaphorically speaking, 'lose track of oneself'. While he acknowledges that there is still uncertainty as regards the 'exact function of this core of intrinsic activity', he speculates that:

> it represents unconscious and continuously on-going processes that are necessary to maintain a coherent neuronal representation of the "self." We believe that irrespective of how focused we are on a specific task [such task-based focus implies lower levels of DMN activity] and no matter how computationally demanding that task is, we cannot, metaphorically speaking, "lose track of ourselves". At all times, the brain needs to have a coherent mental model of the self. Cognitive faculties that might be administered by this model include having a sense of who we are and where in space we are and the passage of time. (Fransson, 2006, p. 2844)

Fransson's claim that the brain's unceasing and coherent mental model of the self might administer cognitive functions that include such fundamental subjective categories as the 'sense of who we are', conjures up a conception of the self that is unable to lose its moorings or, in short, to unfix itself from its self. If the resting state and DMN literature present a brain and a self preoccupied with daydreaming and fantasy, and characterised by unconstrained mental activity, such activities should, in fact, be regarded as tethered and directed rather than formless and indeterminate.[14]

5 The subject at rest moves elsewhere

We have described how resting state research, as well as disseminations of resting state research within the popular literature, are reconceptualising models of brain and self within – and potentially outside of – the neurosciences. While such transformations are in certain ways building on – and committed to expanding – already established cognitivist frameworks (e.g. note the use and extension of standard psychological constructs such as attention), they are, we suggest, simultaneously delineating a rather different account of the self, one which is ripe for movement into other fields. In this final section: (i) we briefly indicate potential points of convergence between this different account of the self and current areas of preoccupation within the humanities and the social sciences; and (ii) speculate on the ways in which dissemination of resting state research might take place.

The animating force within the humanities and social sciences for much of the ongoing interest in neuroscientific research is a frustration with the Cartesian subject (and its corollary, the cognitivist self), and a search for models of the brain, the self and the body that can be interpreted as offering an alternative. That the resting state field in many

ways positions itself as departing from some of the constraints of cognitive psychology – both in terms of its methods and its modelling of the self – is likely to increase its attractions, therefore, to those preoccupied by the limits to cognitivism. This research field emphasizes the phenomena of daydreaming and mind-wandering; it moves away from the technics and analytics of stimulus and response, and towards a model in which variability in behaviour and perception are modulated by endogenous, somatic fluctuations (see Table 1). Such preoccupations are shared by many of those currently working within the humanities and the social sciences on how to conceptualize, interpret and bring to life bodily and psychological movement (e.g. (Sheets-Johnstone, 1999; Henriques, 2010)). Undoubtedly, the attention being given within resting state / DMN research to the delineation and interpretation of a complex internal world cannot but be of interest to those weary of the cognitive orthodoxy in which it is the subject's responses to environmental stimuli that is the primary conceptual lens for analysis.

But it is apposite to consider some of the potential dangers of interdisciplinary intersection. Resting state research is dependent on a whole series of neuroscientific findings from numerous disciplinary specialisms. Such research therefore employs a heterogeneous and complex set of constructs – such as 'self', 'self-processing' and attention – that have complex genealogies even within the terrain of the neurosciences, let alone outside of them. As the field of neuroscientific resting state research grows and begins the process of consolidation, there is an inevitable process of black-boxing – both of constructs and of experimental findings (Latour, 1987, p. 131). Much of the analytic elegance as well as potency of the concept of the DMN, for example, derives from the way in which it has been mapped on to a series of other complex, and heterogeneous

constructs that, we argue, characterize its function and mode of operation. Thus for example, scientific discussions within the field operate with key distinctions being made between: introspection/exterospection; self-related and/non-self-related; and 'internally focused'/'externally focused'. It is important to understand how and with what theoretical consequences such distinctions have been consolidated through experimental designs as well as through model building. Consider, for example, how the following quotation gathers together items under the umbrella category of the 'self-referential':

> the DMN is involved in the evaluation of potentially survival-salient information from the body and the world: perspective taking of the desires, beliefs, and intentions of others and in remembering the past as well as planning the future (2–4). All of these putative functions are self-referential in nature. (Sheline *et al*, 2009)

There is an extensive body of research within the humanities and social sciences that has interrogated both historically and conceptually how different models of self imply very different conceptualizations of 'perspective taking' (e.g. through different theories of identification, empathy and the theory of other minds, e.g. (Leys, 1993)); of relations to one's body and to the world; and of how to articulate the relation between self and other, past and present. How and in what sense '[a]ll … [the] putative functions' that Sheline describes in the quotation above are to be conceptualized as 'self-referential', as well as operationalized experimentally, begs a significant analytic as well as methodological question. There is need for caution, then, is assessing scientific research that associates

the DMN with ‘self-referential functions’, let alone with aspects of the self *per se* – and the social sciences and humanities may have much to contribute (Choudhury *et al*, 2009) to ongoing debates within the already multidisciplinary resting state neuroscientific research field.

* * * * *

It is becoming increasingly common to argue that neuroscience is reshaping models of subjectivity and personhood in the West. On one such account, that of Fernando Vidal, an historian of the human sciences, the human being is now 'specified by the property of «brainhood», i.e. the property or quality of *being*, rather than simply *having* a brain’ (Vidal, 2009, p. 5). To assess Vidal’s contention regarding ‘brainhood’ – that to be a human being today is to ‘be a brain’ – demands that we understand what ‘a brain’, today, is. How, in other words, is the brain that is said to underpin our personhood being conceptualized within and beyond the neuroscientific laboratories? Brains that are emotional, brains that are neuroplastic, and brains that are characterized by mirror neurons are arguably beginning to make significant inroads into public discourse, and to be themselves subjected to critical interrogation (Rubin, 2009; Rees, 2010). But while the emergent field of resting state research is, as we have demonstrated, already making a significant impact both empirically and conceptually within the neurosciences, it has as yet not been subject to any sustained critical analysis from a perspective not wholly embedded within neuroscience.

That has been the task we have set ourselves in this paper, through offering a schematic outline of the field’s genealogy and an initial assessment of how it is

reconfiguring models of brain-environment relations and of the self. The field could be characterized as one element within a larger and heterogeneous set of research practices that are challenging and reorienting certain features of orthodox cognitive neuroscience. The impact and extent of the field's reorderings within as well as beyond the neurosciences are not yet clear. What is clear is that this nascent field is both deeply engaged with and raising to greater visibility many problematics – mind-wandering and day-dreaming, somatic rhythms, introspection, memory and the anticipation of the future, the consolidation and experiencing of the self – that are also topics of live debate and enquiry within the social sciences and the humanities. Both these latter disciplinary domains are, moreover, currently preoccupied with how to use and respond to insights from other fields of expertise when conducting conceptual and empirical explorations of self and subjectivity.

We have indicated how the resting state research field has reworked most of these axes such that the resting brain is now characterized by ceaseless activity, exertion, industriousness and movement. (The only axis that has not obviously been reworked is the affectively freighted axis that opposes rest to agitation, distress or trouble.) We have also seen the ease with which the focus can move between analysing a 'resting' state metabolically, physiologically and psychologically. Resting state researchers' characterizations of the 'resting brain' are, indeed, largely intended to be characterizations of *the brain* (whether at a metabolic, physiological or psychological level).[15] Nonetheless, neuroscientific styles of thought are frequently underpinned by what Vidal has described as a 'brain-self-consubstantiality' (Vidal, 2009, p. 7), such that the 'self' quickly becomes co-terminous with those attributes of the brain. As research

findings regarding the resting state and the DMN move further afield, then, it becomes likely that the industriousness of a daydreaming brain will metonymically and additionally become an account of the industriousness of a daydreaming subject. Such a process will be assisted by the ease with which the concept of the 'default' in the default mode literature has shifted from meaning that which is programmed into a system, to that which is the neutral state of the system, to that which the system 'naturally' returns to – and hence, perhaps, to connoting the 'core' of the very human subject.

What is noticeable in the rise to visibility of resting state research is the language used to describe and conceptualize the new scientific object. Both the specialist and popular scientific literature frequently employ tropes connoting wildness or an underside when describing the resting state and the DMN. Raichle's two papers (one specialist, one popular science) entitled 'The brain's dark energy' (Raichle, 2006; Raichle, 2010) point to a fundamental and mysterious property of the brain; Jarrett (in a popular article), comments, in a similar vein, that 'Perhaps resting brain activity, and the mind-wandering it gives rise to, is psychology's very own *dark matter*' (Jarrett, 2009). Others invoke the well-worn trope of exploration: leading neuroscientist Giulio Tononi describes 'the discovery of a major system within the brain, an organ within an organ, that hid for decades right before our eyes', and comments that 'It's like finding a new continent' (Tononi, quoted in (Glausiusz, 2009)). Buckner and Vincent explain that 'We are in uncharted territory' (Buckner and Vincent, 2007, p. 1095). But the very moment at which this mysterious new object comes into view is also the moment in which there is a drive either to rebut its strangeness (e.g. Morcom and Fletcher's unease that 'mysterious

functions' might be attributed to the resting brain (Morcom and Fletcher, 2007)), or to render the new object co-terminous with other, more familiar knowledges and constructs.

In the course of the paper, we have argued that the 'new continent' of the default mode network is – as it is ushered into the light – being mapped, filled in, and hence reconceptualised as positivity. In the process, many of the previous characteristics and connotations of 'rest', and the constructs associated with it, are being reframed and/or overturned. In the eagerness with which 'rest' is being redescribed as the brain's industriousness, the moment of uncovering the mystery of the resting state is also, perhaps, the moment in which its mystery is colonized. Resting state research has helped to open up to neuroscience what was hitherto unquantifiable inner experience, and, in so doing, has destabilized many of the assumptions built into the models of cognitive science. For the social sciences and humanities to engage with resting state research, then, holds open the possibility of engaging with, and contributing to the building of, a different model of the self and of subjectivity from that one familiar to us by dint of the dominance of orthodox cognitive psychology. But we have also argued that the resting state field is simultaneously engaged in a reworking of cognitive constructs (such as attention and of memory). Default mode network research is both intimate with sub-fields within (orthodox) cognitive neuroscience and dependent upon them. The openings beyond cognitivism could, then, also be in the process of being shut down: memory, for example, is further dissociated from Proust and instead configured as a 'knowledge base' with which 'to guide our lives'. We write at a moment in which to borrow from resting state research enables the possibility of borrowing in a currency different from that of cognitive – and cognitivist – science. Whether those exchanges will take place in a

different currency or, as both the resting state field and the exchanges grow, return to the same currency, remains to be seen.

Notes:

[1] It is far from clear whether the arrival of resting state research heralds a 'paradigm shift' in the strictly Kuhnian sense. In the wider research project – of which this paper is but one part – we are attempting to trace in greater detail the epistemological, technological and material contexts that surrounded the emergence of this field.

[2] We thank one of our anonymous reviewers for reminding us of these precedents.

[3] Buckner and colleagues (Buckner *et al*, 2008) note that references to 'default mode' are first found in the literature on cognition, in other words prior to the term's appearance in explanations of neural and metabolic phenomena.

[4] For a visual example of the temporal dynamics in an fMRI dataset, see: Daniel Margulies and Chris Sharp, Untitled (The effect of Stravinsky's Rite of Spring and Kant's 3rd Critique on the human brain: a functional magnetic resonance imaging approach) at <http://vimeo.com/9871689>, which presents real-time fMRI data of a single individual listening to music. Similar fluctuations are also present in the absence of any overt sensory or behavioural activity.

[5] e.g., David Ingvar's research (Ingvar, 1985) on high resting blood flow in prefrontal cortex, which he attributed to spontaneous self-generated mental activity of the resting human brain.

[6] The assertion that the research communities were independent from one another prior to 2003 can be justified by the lack of any prior cross citations. This claim is supported by the consistency with which Raichle cites Biswal as the seminal researcher in the field in articles and lectures appearing after 2003 (for example: *<video.google.com/videoplay?docid=7393045011768458913>*). From the perspective of

the surrounding research community, personal correspondence with numerous neuroimaging researchers supports the early general neglect of the 'task-induced deactivations' Raichle was describing. Likewise, Biswal's findings ran so contrary to the popular assumptions in the field that his findings were attacked (personal communication). Another example comes from the closing discussion of the first international conference on resting state research in December 2008, where a participant commended Biswal's perseverance by quoting Ghandi: "First they ignore you, then they ridicule you, then they fight you, then you win." To which Biswal responded: "… and we all know what happened to Ghandi … they shot him."

[7] This critique came rather late: the paper was initially received by the journal in the summer of 2006 — more than half a decade after the publication of Raichle and colleagues' 2001 papers.

[8] From Weinberg's computer programming primer (Weinberg, 1966): 'The use of default attributes can contribute to the ease of writing and modifying a program'.

[9] We thank one of our anonymous reviewers for this important point.

[10] Raichle is quoting from Seneca: 'The fact that the body is lying down is no reason for supposing that the mind is at peace. Rest is … far from restful' (Seneca, ~60 A.D. [1969]). Interestingly, Seneca is describing the state of individual who has not found serenity because his emotions are in turmoil and hence his sleep is 'far from restful'; Raichle, in contrast, quotes Seneca in the service of embedding the restlessness of rest as a generic rather than phenomenologically (and ethically) specific condition.

[11] Such evolutionary preoccupations abound in the cognitive neuroscience literature. A core question within the literature on spontaneous activity, often addressed by Raichle, is

what evolutionary advantage the investment of neural energy in spontaneous fluctuations might serve.

[12] The accounts of mind-wandering and daydreaming that appear in resting state and DMN research in fact draw heavily on models developed in psychology that can be traced back several decades to the work of Jerome Singer and colleagues (e.g. Singer, 1966). But any effect that such accounts might have in reorienting conceptualizations of the self beyond scientific circles will be by dint of their association with cognitive neuroscientific findings from the twenty-first century rather than psychological findings from the 1960s.

[13] It is fascinating that James notes that the 'curious state of inhibition' that he is describing can be 'produced at will by fixing the eyes on vacancy', and that some individuals are able 'voluntarily [to] empty their minds and "think of nothing"' (James, 1890, p. 404). James here almost exactly describes the instructions commonly given to research subjects in resting state studies.

[14] Incidentally, we should note here how easily Fransson moves between the neuronal and the psychological. Spontaneous, intrinsic fluctuations, similar to those in the DMN, are ubiquitous in the brain. To claim a specific *psychological* role of the DMN fluctuations at this stage is a tempting hypothesis, but represents the blurring of distinct concepts from the two merging research agendas.

[15] Characterizing the brain on a psychological level would, in this context, refer to the attempt to delineate a psychological state that corresponds to a baseline (or 'neutral') brain state. The basic question that such a characterization responds to is: What is the psychological state of a

brain at rest? This project points at a vertex between the two fields of Biswal (intrinsic neural activity) and Raichle (intrinsic psychological activity).

Figure and Table Captions:

Figure 1: An example of a standard cross-hair used for baseline fixation during psychological task paradigms.

Figure 2: Traditionally, cognitive neuroscience studies focus on the brain regions that covary in activity levels with a task model, as depicted here in a standard on-off 'boxcar' design. 'The Flipping of Contrasts' by Shulman and colleagues (Shulman *et al*, 1997) involved inverting the traditional contrast of 'task-over-baseline' in order to assess regions that were more active during the resting condition.

Figure 3: Regions that consistently decreased in activity during task performance (later dubbed the 'default mode network'), as originally depicted in a meta-analysis of nine positron emission tomography studies by Shulman and colleagues (1997).

Figure 4: Bharat Biswal and colleagues (1995) first demonstrated that regions involved in a motor tapping task (a) were also correlated in their spontaneous activity during rest (b).

Acknowledgements: Felicity Callard acknowledges the financial support of the NIHR Biomedical Research Centre for Mental Health, South London and Maudsley NHS Foundation Trust/Institute of Psychiatry (King's College London). Daniel Margulies acknowledges the financial support of the Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig. They both acknowledge the creative support of The Neuro Bureau (Berlin), as well as the European Neuroscience and Society Network (funded by the European Science Foundation (ESF)) for providing the opportunity to initiate this

collaboration. They thank the anonymous peer reviewers for their helpful suggestions, as well as the audiences who responded to earlier versions of this paper presented at symposia organized by the Zentrum für Literatur- und Kulturforschung (Berlin), University of Chicago/Max Planck Institute for the History of Science (Berlin), and the University of Edinburgh.

Table 1: The 'old' cognitive neuroscience paradigm and the 'new' resting state / DMN paradigm

Old paradigm	*New paradigm*
Over-arching scientific framework	
Brain function largely determined by *extrinsic / evoked* activity	Brain function largely determined by *intrinsic / spontaneous* activity
Primacy of cognitive psychology	Other disciplines and sub-disciplines involved / jostling for a space / required for the field to progress
Scientific method and objects of study	
Collection of task and rest data	Collection of resting state data
Use of a controlled stimulus	No deliberate stimulus
Psychological manipulation of experimental subject	Experimental subject psychologically unconstrained
Mental chronometry*	Rendering visible of the rhythm of intrinsic dynamics
Emphasis on brain activity occurring more rapidly than 1Hz	Emphasis on slow temporal resting state cycles of 0.05 Hz
The elicited and observable	The spontaneous and internal
Implications for conceptualization of brain and self	
Individuals are differentiated (and potentially classified) through their response to tasks: a behavioural-perceptual constitution of subjectivity	Individuals are differentiated (and potentially classified) through the intrinsic operation of their DMN
The perceiving, externally goal-directed self	The mind-wandering, internally-focused self
Brain implicitly inactive in absence of environmental stimulus	Brain always active irrespective of environmental stimulus
Rest implicitly assumed to be more restful that 'non-rest'	Rest refigured into active psychological states
Variability in behaviour & perception is noise	Variability in behaviour & perception is modulated by endogenous fluctuations
Localization specific functional modules in the	Resting-state networks are more 'natural' and

brain	'core' with respect to functional divisions
‘Self’ as a localizable conceptual representation	‘Self’ as a distributed network in the brain, largely driven by spontaneous activity
A cognitivist self	Beyond the cognitivist self?

* Mental chronometry is the use of response time in perceptual and motor tasks to infer the content, duration, and temporal sequencing of cognitive operations.

References

Andrews-Hanna, J. R., Reidler, J. S., Sepulcre, J., Poulin, R. and Buckner, R. L. (2010) Functional-Anatomic Fractionation of the Brain's Default Network. *Neuron,* 65(4): 550-562.

Bar, M. (2007) The proactive brain: using analogies and associations to generate predictions. *Trends in Cognitive Sciences,* 11(7): 280-289.

Bar, M. (2009) The proactive brain: memory for predictions. *Phil Trans R Soc B,* 364(1235–1243).

Biswal, B., Yetkin, F. Z., Haughton, V. M. and Hyde, J. S. (1995) Functional connectivity in the motor cortex of resting human brain using echo-planar MRI. *Magnetic Resonance in Medicine,* 34(4): 537-541.

Biswal, B. B. and Kannurpatti, S. (2009) Resting-state functional connectivity in animal models: modulations by exsanguination. *Methods Mol Biol,* 489255–274.

Biswal, B. B., Mennes, M., Zuo, X. N., Gohel, S., Kelly, C., Smith, S. M., Beckmann, C. F., Adelstein, J. S., Buckner, R. L., Colcombe, S., Dogonowski, A. M., Ernst, M., Fair, D., Hampson, M., Hoptman, M. J., Hyde, J. S., Kiviniemi, V. J., Kotter, R., Li, S. J., Lin, C. P., Lowe, M. J., Mackay, C., Madden, D. J., Madsen, K. H., Margulies, D. S., Mayberg, H. S., Mcmahon, K., Monk, C. S., Mostofsky, S. H., Nagel, B. J., Pekar, J. J., Peltier, S. J., Petersen, S. E., Riedl, V., Rombouts, S. A., Rypma, B., Schlaggar, B. L., Schmidt, S., Seidler, R. D., Siegle, G. J., Sorg, C., Teng, G. J., Veijola, J., Villringer, A., Walter, M., Wang, L., Weng, X. C., Whitfield-Gabrieli, S., Williamson, P., Windischberger, C., Zang, Y. F., Zhang, H. Y., Castellanos, F. X. and Milham, M. P. (2010) Toward discovery science of human brain function. *Proc Natl Acad Sci U S A,* 107(10): 4734-9.

Boly, M., Phillips, C., Tshibanda, L., Vanhaudenhuyse, A., Schabus, M., Dang-Vu, T. T., Moonen, G., Hustinx, R., Maquet, P. and Laureys, S. (2008) Intrinsic brain activity in altered states of consciousness: how conscious is the default mode of brain function? *Ann N Y Acad Sci,* 1129119-29.

Brown, T. G. (1914) On the nature of the fundamental activity of the nervous centres; together with an analysis of the conditioning of rhythmic activity in progression, and a theory of the evolution of function in the nervous system. *The Journal of Physiology,* 48(1): 18-46.

Buckner, R. L., Andrews-Hanna, J. R. and Schacter, D. L. (2008) The brain's default network: anatomy, function, and relevance to disease. *Ann NY Acad Sci,* 11241–38.

Buckner, R. L. and Vincent, J. L. (2007) Unrest at rest: Default activity and spontaneous network correlations. *NeuroImage,* 37(4): 1091-1096.

Bullmore, E. and Sporns, O. (2009) Complex brain networks: graph theoretical analysis of structural and functional systems. *Nat Rev Neurosci,* 10(3): 186-98.

Choudhury, S., Nagel, S. K. and Slaby, J. (2009) Critical Neuroscience: Linking Neuroscience and Society through Critical Practice. *BioSocieties,* 4(1): 61-77.

Christoff, K., Gordon, A. M., Smallwood, J., Smith, R. and Schooler, J. W. (2009) Experience sampling during fMRI reveals default network and executive system contributions to mind wandering. *Proceedings of the National Academy of Sciences,* 106(21): 8719-8724.

Connolly, W. E. (2002) *Neuropolitics: Thinking, Culture, Speed*, Minneapolis, University of Minnesota Press.

Cromby, J. (2007) Integrating social science with neuroscience: potentials and problems. *BioSocieties*, 2(2): 149–169.

Damasio, A. (1994) *Descartes' Error: Emotion, Reason, and the Human Brain*, New York, Avon.

Damasio, A. (2000) *The Feeling of What Happens: Body, Emotion and the Making of Consciousness*, London, Vintage.

Damasio, A. (2004) *Looking for Spinoza: Joy, Sorrow and the Feeling Brain*, London, Vintage.

Dapretto, M., Davies, M. S., Pfeifer, J. H., Scott, A. A., Sigman, M., Bookheimer, S. Y. and Iacoboni, M. (2006) Understanding emotions in others: mirror neuron dysfunction in children with autism spectrum disorders. *Nat Neurosci*, 9(1): 28-30.

Di Martino, A., Scheres, A., Margulies, D. S., Kelly, A. M., Uddin, L. Q., Shehzad, Z., Biswal, B., Walters, J. R., Castellanos, F. X. and Milham, M. P. (2008) Functional connectivity of human striatum: a resting state FMRI study. *Cereb Cortex*, 18(12): 2735-47.

Fair, D. A., Cohen, A. L., Power, J. D., Dosenbach, N. U., Church, J. A., Miezin, F. M., Schlaggar, B. L. and Petersen, S. E. (2009) Functional brain networks develop from a "local to distributed" organization. *PLoS Comput Biol*, 5(5): e1000381.

Fornito, A. and Bullmore, E. T. (2010) What can spontaneous fluctuations of the blood oxygenation-level-dependent signal tell us about psychiatric disorders? *Curr Opin Psychiatry*.

Fox, M. (2007) Brain study finds the stuff of daydreams. Thomson Reuters.

Fox, M. D. and Greicius, M. (2010) Clinical applications of resting state functional connectivity. *Front Syst Neurosci*, 419.

Fransson, P. (2006) How default is the default mode of brain function?: Further evidence from intrinsic BOLD signal fluctuations. *Neuropsychologia*, 44(14): 2836-2845.

Fransson, P., Skiold, B., Horsch, S., Nordell, A., Blennow, M., Lagercrantz, H. and Aden, U. (2007) Resting-state networks in the infant brain. *Proc Natl Acad Sci U S A*, 104(39): 15531-6.

Freud, S. (1908) Writers and day-dreaming. IN STRACHEY, J. (Ed.) *The Standard Edition of the Complete Psychological Works of Sigmund Freud.* London, Hogarth Press and the Institute of Psycho-Analysis.

Friston, K. J., Frith, C. D., Liddle, P. F. and Frackowiak, R. S. (1993) Functional connectivity: the principal-component analysis of large (PET) data sets. *J Cereb Blood Flow Metab*, 13(1): 5-14.

Fukunaga, M., Horovitz, S. G., Van Gelderen, P., De Zwart, J. A., Jansma, J. M., Ikonomidou, V. N., Chu, R., Deckers, R. H., Leopold, D. A. and Duyn, J. H. (2006) Large-amplitude, spatially correlated fluctuations in BOLD fMRI signals during extended rest and early sleep stages. *Magn Reson Imaging*, 24(8): 979-92.

Gallagher, S. (2000) Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Sciences*, 4(1): 14-21.

Gilbert, S. J., Dumontheil, I., Simons, J. S., Frith, C. D. and Burgess, P. W. (2007) Comment on "Wandering minds: the default network and stimulus-independent thought". *Science,* 31743b.

Glausiusz, J. (2009) Devoted to distraction. *Psychology Today,* (March/April): 84–91.

Goldberg, I., Ullman, S. and Malach, R. (2008) Neuronal correlates of "free will" are associated with regional specialization in the human intrinsic/default network. *Conscious Cogn,* 17(3): 587-601.

Greicius, M. (2008) Resting-state functional connectivity in neuropsychiatric disorders. *Curr Opin Neurol,* 21(4): 424-30.

Greicius, M. D., Krasnow, B., Reiss, A. L. and Menon, V. (2003) Functional connectivity in the resting brain: A network analysis of the default mode hypothesis. *Proceedings of the National Academy of Sciences of the United States of America,* 100(1): 253-258.

Gusnard, D. A., Akbudak, E., Shulman, G. L. and Raichle, M. E. (2001) Medial prefrontal cortex and self-referential mental activity: Relation to a default mode of brain function. *Proceedings of the National Academy of Sciences of the United States of America,* 98(7): 4259-4264.

Gusnard, D. A. and Raichle, M. E. (2001) Searching for a baseline: Functional imaging and the resting human brain. *Nat Rev Neurosci,* 2(10): 685-694.

Hansen, M. B. N. (2004) *New philosophy for New Media,* Cambridge, MA, MIT Press.

Henriques, J. (2010) The vibrations of affect and their propagation on a night out on Kingston's dancehall scene. *Body & Society,* 16(57–89).

Horovitz, S. G., Fukunaga, M., De Zwart, J. A., Van Gelderen, P., Fulton, S. C., Balkin, T. J. and Duyn, J. H. (2008) Low frequency BOLD fluctuations during resting wakefulness and light sleep: a simultaneous EEG-fMRI study. *Hum Brain Mapp,* 29(6): 671-82.

Ingvar, D. (1985) 'Memory of the future': an essay on the temporal organization of conscious awareness. *Hum Neurobiol,* 4127–136.

James, W. (1890) *The Principles of Psychology,* New York, Dover Publications.

Jarrett, C. (2009) The restless brain. *The Psychologist,* 22(10): 836–839.

Kelly, A. M., Di Martino, A., Uddin, L. Q., Shehzad, Z., Gee, D. G., Reiss, P. T., Margulies, D. S., Castellanos, F. X. and Milham, M. P. (2009) Development of anterior cingulate functional connectivity from late childhood to early adulthood. *Cereb Cortex,* 19(3): 640-57.

Krienen, F. M. and Buckner, R. L. (2009) Segregated fronto-cerebellar circuits revealed by intrinsic functional connectivity. *Cereb Cortex,* 19(10): 2485-97.

Latour, B. (1987) *Science in action : how to follow scientists and engineers through society,* Cambridge, Mass., Harvard University Press.

Ledoux, J. E. (1996) *The emotional brain: the mysterious underpinnings of emotional life,* New York, Simon & Schuster.

Lehrer, J. (2008) Daydream achiever. *Boston Globe.*

Leys, R. (1993) Mead's Voices: imitation as foundation, or, the struggle against mimesis. *Critical Inquiry,* 19277–307.

Lieberman, M. D. (2007) Social cognitive neuroscience: a review of core processes. *Annu Rev Psychol,* 58259-89.

Llinás, R. R. (2001) *I of the Vortex: From neurons to self,* Cambridge, MA, MIT Press.

Malabou, C. (2008) *What Should We Do with Our Brain?*, New York, Fordham University Press.

Margulies, D. S., Kelly, A. M., Uddin, L. Q., Biswal, B. B., Castellanos, F. X. and Milham, M. P. (2007) Mapping the functional connectivity of anterior cingulate cortex. *Neuroimage,* 37(2): 579-88.

Margulies, D. S., Vincent, J. L., Kelly, C., Lohmann, G., Uddin, L. Q., Biswal, B. B., Villringer, A., Castellanos, F. X., Milham, M. P. and Petrides, M. (2009) Precuneus shares intrinsic functional architecture in humans and monkeys. *Proc Natl Acad Sci U S A,* 106(47): 20069-74.

Martin, E. (2007) *Bipolar Expeditions: Mania and depression in American culture,* Princeton and Oxford, Princeton University Press.

Mason, M. F., Norton, M. I., Van Horn, J. D., Wegner, D. M., Grafton, S. T. and Macrae, C. N. (2007) Wandering minds: the default network and stimulus-independent thought. *Science,* 315393–395.

Moll, J., De Oliveira-Souza, R., Garrido, G. J., Bramati, I. E., Caparelli-Daquer, E. M., Paiva, M. L., Zahn, R. and Grafman, J. (2007) The self as a moral agent: linking the neural bases of social agency and moral sensitivity. *Soc Neurosci,* 2(3-4): 336-52.

Morcom, A. M. and Fletcher, P. C. (2007) Does the brain have a baseline? Why we should be resisting a rest. *NeuroImage,* 37(4):1073–1082.

Moss, H. and Damasio, A. R. (2001) Emotion, cognition, and the human brain. *Ann N Y Acad Sci,* 93598-100.

Orbach, S. (2009) *Bodies,* London, Profile.

Panksepp, J. (1998) *Affective Neuroscience: the foundations of human and animal emotions,* New York; Oxford, Oxford University Press.

Papoulias, C. and Callard, F. (2010) Biology's gift: interrogating the turn to affect. *Body & Society,* 16(1): 29–56.

Phelps, E. A. and Ledoux, J. E. (2005) Contributions of the amygdala to emotion processing: from animal models to human behavior. *Neuron,* 48(2): 175-87.

Raichle, M. E. (2006) The brain's dark energy. *Science,* 3141249–1250.

Raichle, M. E. (2009) A Paradigm Shift in Functional Brain Imaging. *J. Neurosci.,* 29(41): 12729-12734.

Raichle, M. E. (2010) The Brain's Dark Energy. *Scientific American,* 302(March): 44–49.

Raichle, M. E. and Snyder, A. Z. (2007) A default mode of brain function: A brief history of an evolving idea. *NeuroImage,* 371083–1090.

Rees, T. (2010) Being neurologically human today: Life and science and adult cerebral plasticity (an ethical analysis). *American Ethnologist,* 37(1): 150-166.

Rizzolatti, G. and Arbib, M. A. (1998) Language within our grasp. *Trends Neurosci,* 21(5): 188-94.

Rizzolatti, G. and Craighero, L. (2004) The mirror-neuron system. *Annual Review of Neuroscience,* 27(1): 169-192.

Rose, N. (1998) *Inventing Our Selves: Psychology, power, and personhood,* Cambridge, Cambridge University Press.

Rose, N. (2007) *The Politics of Life Itself: Biomedicine, power, and subjectivity in the twenty-first century,* Princeton, NJ, Princeton University Press.

Roy, A. K., Shehzad, Z., Margulies, D. S., Kelly, A. M., Uddin, L. Q., Gotimer, K., Biswal, B. B., Castellanos, F. X. and Milham, M. P. (2009) Functional connectivity of the human amygdala using resting state fMRI. *Neuroimage,* 45(2): 614-26.

Rubin, B. P. (2009) Changing Brains: The Emergence of the Field of Adult Neurogenesis. *BioSocieties,* 4(4): 407-424.

Saey, T. H. (2009) You are who you are by default. *ScienceNews.*

Schilbach, L., Eickhoff, S. B., Rotarska-Jagiela, A., Fink, G. R. and Vogeley, K. (2008) Minds at rest? Social cognition as the default mode of cognizing and its putative relationship to the "default system" of the brain. *Conscious Cogn,* 17(2): 457-67.

Seeley, W. W., Crawford, R. K., Zhou, J., Miller, B. L. and Greicius, M. D. (2009) Neurodegenerative diseases target large-scale human brain networks. *Neuron,* 62(1): 42-52.

Seneca, L. D. (~60 A.D. [1969]) *Letters from a Stoic: epistulae morales ad Lucilium,* New York, Penguin Books.

Sheets-Johnstone, M. (1999) *The Primacy of Movement,* Amsterdam, J Benjamins.

Sheline, Y. I., Barch, D. M., Price, J. L., Rundle, M. M., Vaishnavi, S. N., Snyder, A. Z., Mintun, M. A., Wang, S., Coalson, R. S. and Raichle, M. E. (2009) The default mode network and self-referential processes in depression. *Proc Natl Acad Sci U S A,* 106(6): 1942-7.

Shulman, G. L., Fiez, J. A., Corbetta, M., Buckner, R. L., Miezin, F. M., Raichle, M. E. and Petersen, S. E. (1997) Common Blood Flow Changes across Visual Tasks: II. Decreases in Cerebral Cortex. *Journal of Cognitive Neuroscience,* 9(5): 648-663.

Singer, J. L. (1966) *Daydreaming: An introduction to the experimental study of inner experience,* New York, Random House.

Smallwood, J., Beach, E., Schooler, J. W. and Handy, T. C. (2008) Going AWOL in the brain: mind wandering redues cortical analysis of external events. *Journal of Cognitive Neuroscience,* 20(3): 458–469.

Smallwood, J. and Schooler, J. W. (2006) The restless mind. *Psychological Bulletin,* 132(6): 946–958.

Smith, S. M., Fox, P. T., Miller, K. L., Glahn, D. C., Fox, P. M., Mackay, C. E., Filippini, N., Watkins, K. E., Toro, R., Laird, A. R. and Beckmann, C. F. (2009) Correspondence of the brain's functional architecture during activation and rest. *Proc Natl Acad Sci U S A,* 106(31): 13040-5.

Spreng, R. N., Mar, R. A. and Kim, A. S. (2009) The common neural basis of autobiographical memory, prospection, navigation, theory of mind, and the default mode: a quantitative meta-analysis. *J Cogn Neurosci,* 21(3): 489-510.

Stafford, B. M. (2007) *Echo Objects: the cognitive work of images,* Chicago, IL, Chicago University Press.

Thrift, N. (2008) Pass it on: Towards a political economy of propensity. *Emotion, Space and Society,* 1(2): 83-96.

Turkle, S. (1995) *Life on the Screen: Identity in the age of the internet,* New York, London, Simon & Schuster.

Valeo, T. (2008) Perchance to daydream ... and degenerate. *Dana Foundation.*

Van Dijk, K. R., Hedden, T., Venkataraman, A., Evans, K. C., Lazar, S. W. and Buckner, R. L. (2010) Intrinsic functional connectivity as a tool for human connectomics: theory, properties, and optimization. *J Neurophysiol,* 103(1): 297-321.

Vidal, F. (2009) Brainhood, anthropological figure of modernity. *History of the Human Sciences,* 22(1): 5–36.

Vincent, J. L., Kahn, I., Snyder, A. Z., Raichle, M. E. and Buckner, R. L. (2008) Evidence for a frontoparietal control system revealed by intrinsic functional connectivity. *J Neurophysiol,* 100(6): 3328-42.

Vincent, J. L., Kahn, I., Van Essen, D. C. and Buckner, R. L. (2010) Functional connectivity of the macaque posterior parahippocampal cortex. *J Neurophysiol,* 103(2): 793-800.

Vincent, J. L., Patel, G. H., Fox, M. D., Snyder, A. Z., Baker, J. T., Van Essen, D. C., Zempel, J. M., Snyder, L. H., Corbetta, M. and Raichle, M. E. (2007) Intrinsic functional architecture in the anaesthetized monkey brain. *Nature,* 447(7140): 83-6.

Weinberg, G. M. (1966) *PL/I Programming Primer,* New York, Mc-Graw-Hill.

Whitfield-Gabrieli, S. and Gabrieli, J. (2010) Idle minds and what they may say about intelligence. *Scientific American.*

Williams, J. H., Whiten, A., Suddendorf, T. and Perrett, D. I. (2001) Imitation, mirror neurons and autism. *Neurosci Biobehav Rev,* 25(4): 287-95.

Authors' Contact Details / Biographies:

Felicity Callard, PhD [corresponding author]

King's College London, Institute of Psychiatry

NIHR Biomedical Research Centre for Mental Health

South London & Maudsley NHS Foundation Trust and Institute of Psychiatry,
King's College London

Felicity.callard@kcl.ac.uk

Biography:

Felicity Callard has disciplinary expertise in the history and living present of psychiatry and in cultural/social theory. She is currently a postdoctoral research fellow at the Max Planck Institute for the History of Science, Berlin, where she is working on a history of experimental attempts to investigate daydreaming. She also retains an affiliation to the NIHR Biomedical Research Centre for Mental Health, South London & Maudsley NHS Foundation Trust / Institute of Psychiatry, King's College London, where she conducted the research for this collaborative paper. One strand of her research focuses on how appropriations and flows of

concepts occur in this current moment of cross-disciplinary exchange between the neurosciences, social sciences and humanities.

Daniel S. Margulies, PhD

Mind & Brain Institute, Humboldt Universität zu Berlin.

Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig.

Biography:

Daniel Margulies has disciplinary expertise in functional neuroimaging of the brain ‘at rest’. He is currently a postdoctoral research fellow at the Mind & Brain Institute of Humboldt University and the Max Planck for Human Cognition and Brain Sciences, investigating functional neuroanatomy and how individual patterns of behaviour relate to the organization of large-scale brain networks. Before neuroscience, he studied philosophy and literature, and continues to explore intersections of neuroscience with the arts and psychoanalysis.

Figure 1

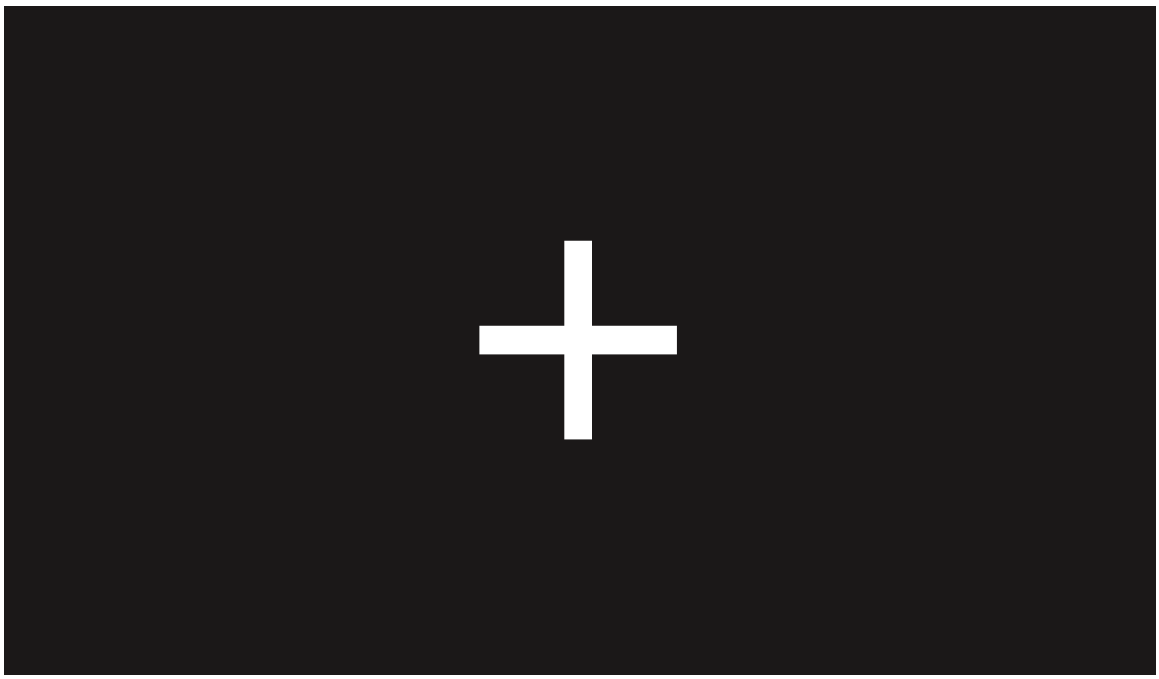


Figure 2

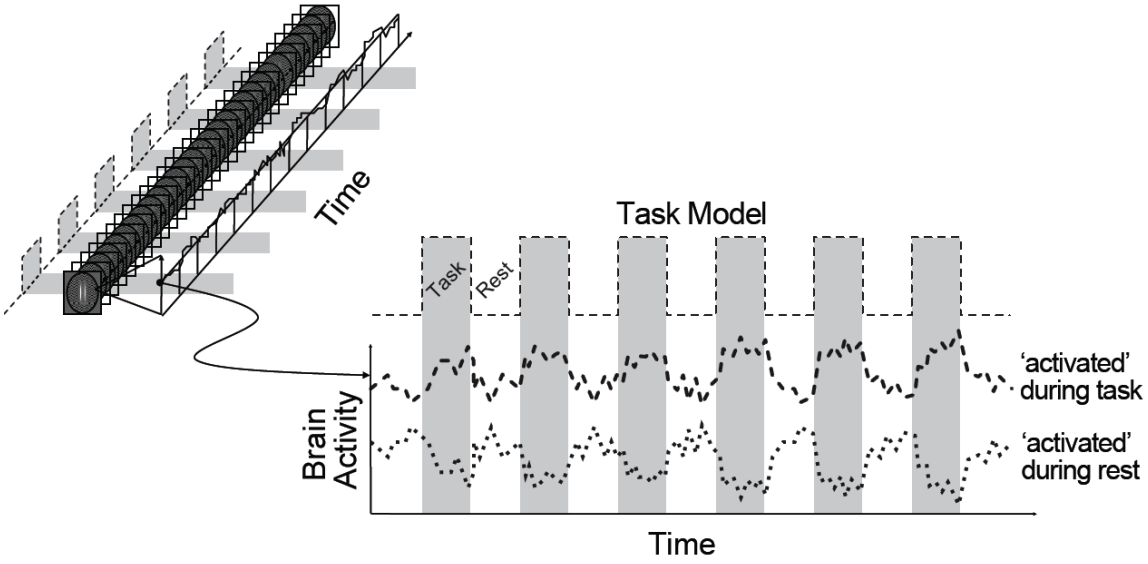
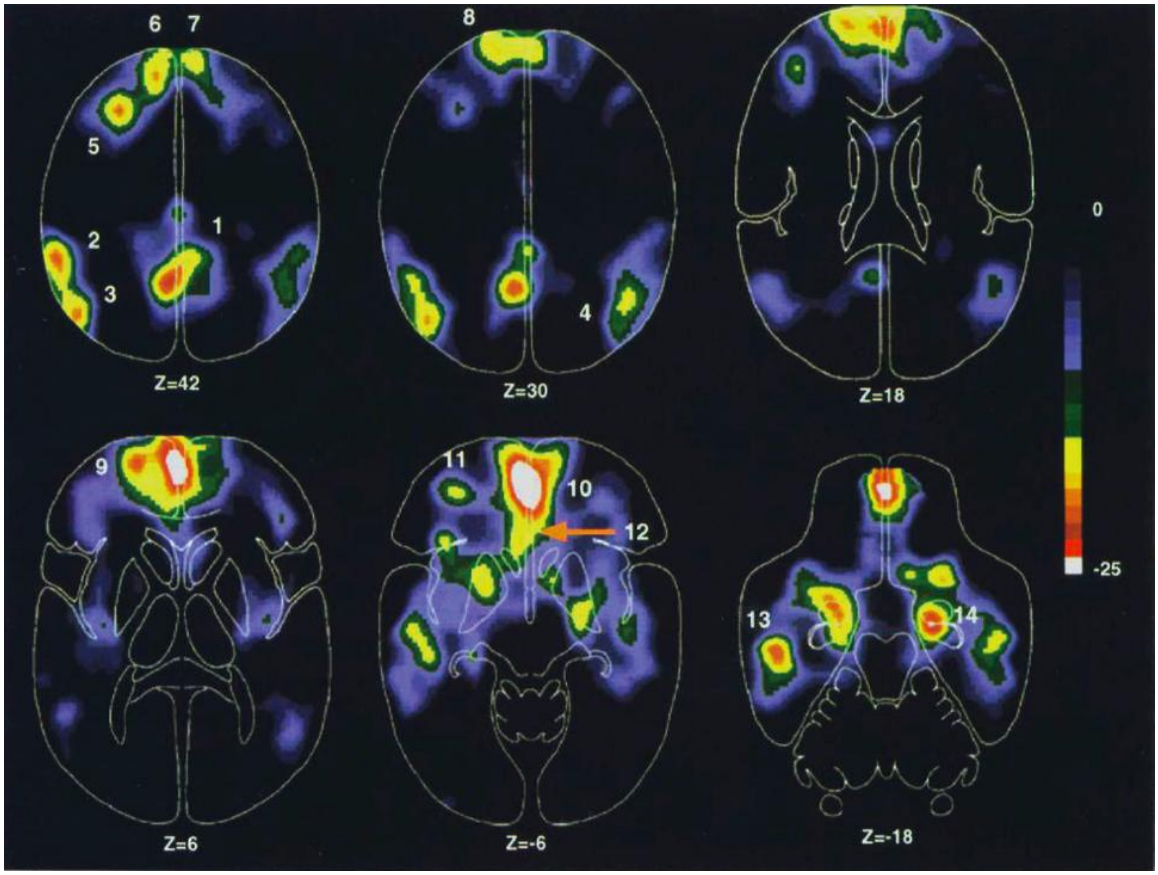

Time
Task Model
Task
Rest
'activated' during task
'activated' during rest
Brain Activity
Time

Figure 3



Areas involved in motor tapping task

Areas correlated with seed point at rest