

Geography and neuroscience

Pykett, Jessica

DOI:

[10.1111/tran.12213](https://doi.org/10.1111/tran.12213)

License:

None: All rights reserved

Document Version

Peer reviewed version

Citation for published version (Harvard):

Pykett, J 2018, 'Geography and neuroscience: critical engagements with geography's 'neural turn'', *Transactions of the Institute of British Geographers*, vol. 43, no. 2, pp. 154-169. <https://doi.org/10.1111/tran.12213>

[Link to publication on Research at Birmingham portal](#)

Publisher Rights Statement:

This is the peer reviewed version of the following article: Pykett, J. (2017), Geography and neuroscience: critical engagements with geography's 'neural turn'. *Trans Inst Br Geogr.*, which has been published in final form at doi:10.1111/tran.12213. This article may be used for non-commercial purposes in accordance with Wiley Terms and Conditions for Self-Archiving.

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

- Users may freely distribute the URL that is used to identify this publication.
- Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.
- User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)
- Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Geography and Neuroscience: critical engagements with geography's 'neural turn'

Jessica Pykett

School of Geography, Earth and Environmental Sciences, University of Birmingham

Accepted for publication in *Transactions of the Institute of British Geographers*, 16 Aug 2017

Abstract: Geographers are increasingly interested in understanding the significance of developments in neuroscience, psychology and the behavioural sciences. Indeed, consideration of these disciplines has arguably shaped the trajectories of human geography since at least the 1960s, but its 'neural turn' has only recently been acknowledged. This paper provides an original analysis of the intersections of research on neuroscience and geography. With reference to qualitative interviews with cognitive scientists and neuroscientists based in the UK, it identifies how geographical concepts have been approached within contemporary neuroscience while also identifying the broad trajectories of geographers' engagements with neuroscience. The discussion demonstrates the political implications of these disciplinary trends for a geographical account of brain culture and brain-based explanations in policy and practice. Specifically it proposes the development of a 'critical neuro-geography' capable of providing an overarching analysis of these phenomena. The paper's novel synthesis of hitherto disconnected engagements between geography, cognitive science and neuroscience establishes the rationale for a more sustained and critical engagement between neuroscience and geography sensitive to issues of situated subjectivity, power, inequality and difference.

Keywords: Neuroscience, cognitive science, psychology, geographical thought, embodied cognition, subjectivity

Geography and Neuroscience: critical engagements with geography's 'neural turn'

Introduction: mind, brain and world

Geographers have a long running interest in cognition or mental processes and on explaining the relationship between the mind (primarily perception, memory, consciousness and behavioural prompts) and the world (environment, landscape or context). More recently they have discussed the brain itself and its affective interactions with the world (McCormack, 2007; Thrift 2008; Callard and Papoulias, 2010; Davies, 2010; Gagen, 2015; Pykett, 2015). From their early explorations of psychology, geographers have consistently resisted the internalisation of the mind. As David Ley noted in 1978, the mind is not reducible to the organ of the brain (p45, cited in Pile, 1993: p125):

“...the environment is not in the head. Consciousness cannot break loose from a concrete time-space context, from the realities of everyday living; notions of pure consciousness are as much an abstraction from human experience as any isotropic plain.”

Numerous developments within cognitive science, cognitive and affective neuroscience, and social neuroscienceⁱ provide a timely opportunity for geographers to shape both conceptual and methodological approaches to mind/brain/world interactions. In considering this opportunity – as well as the potential pitfalls – this paper brings together hitherto fragmentary engagements between geography and the neurosciences in order to identify areas of commonality, tensions and potential points of departure for a proposed 'critical

neuro-geography'. It is argued that whilst geographical research has often been informed by both a cognitive and neural perspective, there lacks a concerted effort to articulate what geography itself can contribute to critical political debates around 'brain culture' as a social formation, which refers to the place of neuroscience in society and its specific manifestation in policy and diverse fields of social practice. Fundamental to these debates, it is argued, is the relative extent to which the brain, mind and world are narrated as the locus of behaviour and the source of sociological and scientific explanation.

Particular strands of contemporary cognitive science now take seriously Ley's philosophical proposition that the 'external' world is essential to understanding human nature, thinking and behaviour – demonstrating a concerted diversity of approaches within the neurosciences. Approaches to *distributed cognition*, *situated cognition*, *cognitive ethology*, *embodied or embedded consciousness*, and *consciousness in action* have developed to address the apparent dislocation of the human subject from her environmental context (Clark 1999; Wheeler, 2005; Kingstone et al, 2008; Noë, 2009; Robbins and Aydede 2009). These often conceptual debates have been complemented by recent technological developments which can take experimentation out of laboratory settings. These include 'real-world' or mobile neuroimaging technologies such as mobile EEGs (electroencephalograms) (McDowell et al, 2013), and wearable biosensors/'affective wearables' which can amongst other things provide proxy measures for various emotional states (Picard and Healy 1997). The emergence of *social neuroscience* has also been a significant step-change in contemporary neuroscience research. Social neuroscience has been concerned with outlining the role of neural systems in explaining information processing and – by extension – human behaviour (Cacioppo, 2002: 3). Most famously this

approach has identified the 'mirror neuron', said to be the neural source of empathy, intersubjective understanding and thereby, sociality (Ramachandran, cited in Rose and Abi-Rached, 2013: 146). In parallel with the now widely accepted *plasticity* of the brain, referring to the capacity of the brain to change biologically as a result of experience, there has thus been a rapid increase in interest in the social and environmental contexts of brain development. At the same time, there has been increased interest in the particular mechanisms by which this social and physical world might 'get inside' and shape the brain through emotional arousal and response. Since the 1990s, the advent of *affective neuroscience* which studies the physiology of emotion, including the neural circuitry of positive and negative affects (Davidson and Sutton, 1995) and the role of embodied emotions in decision making (Damasio et al, 1990) is certainly relevant to debates surrounding the 'affective turn' in geography (Thien, 2005; Anderson and Harrison 2006; Thrift 2008; Barnett 2008; Pile 2010; Papoulias and Callard, 2010)).

These neuroscientific developments, in addition to the resurgence of the behavioural sciences are not solely epistemological, disciplinary or methodological concerns; they have political and policy implications in a variety of social spheres which a handful of geographers have begun to investigate. These include: the role of 'neuroeducation' and brain-based teaching and learning in schooling and child development (Kraftl, 2013; Gagen, 2015; Pykett, 2012, Pykett and Disney, 2015); behavioural economics and neuroeconomics within financial decision-making and corporate management tactics (Clark, 2011; McDowell 2011; Pykett, 2013; Pykett and Enright 2016); behavioural science approaches to transport planning and climate change (Barr and Prillwitz, 2014; Yalachkov et al., 2014); and the rise of behavioural public policy targeting the pre-cognitive realm as a technique of 'neuroliberal'

governance (Jones et al. 2013; Whitehead et al., 2017). We might therefore identify something of a 'neural turn' in human geography. For some this indicates an embrace of the neurobiological and neuromolecular style of thought as a means by which to re-materialise a more embodied and affective geography (e.g. McCormack 2007). Others have set out to critically address the constitutive effects of neuroscience itself, for instance in Davies' research on the dangers of reductionism in neuroscience and genetics (Davies, 2010); and the evolution of 'brain culture' (Pykett, 2015). Felicity Callard has contributed more than any to the establishment of both critical neuroscience and psychoanalytic geography perspectives on a range of phenomena including the brain 'at rest', mental health and bioethics, and the body in social theory (e.g. Callard 2006; Papoulias and Callard, 2010; Callard and Margulies 2011). Fitzgerald and Callard 2014 have also identified the novel theoretical approaches which might be advanced for crossing sociocultural and neurobiological research divides. As an interesting counterpoint to the aforementioned movements of cognitive scientists beyond laboratory settings, Callard and Fitzgerald (2015) have shifted sociological and geographical attention to the physical and conceptual spaces of the neuroscience laboratory itself. It is my intention in this paper to build on these emerging currents of thought, but to articulate a specifically *geographical* engagement with developments in the cognitive and neurosciences, with particular attention to implications for political agency and social practice.

The paper is organised around identifying and proposing common ground for research on the cognitive sciences, neurosciences and geography, as well as highlighting the potential conflicts that such a project signifies. The first section broadly identifies how geographical concepts have been dealt with in cognitive science and neuroscience, providing a synthesis

of geographical trends in contemporary cognitive science. This section draws on 9 in depth qualitative interviews conducted with UK-based academic cognitive scientists (including neuroscientists), a behavioural economist and a bio-ethicist between June and December 2013. The interviews explored potential synergies between geography and contemporary cognitive science, not yet identified in any published literature. They provided an opportunity to articulate these synergies in lay language and to reflect on the broad geographical assumptions of practicing cognitive scientists within a rapidly evolving field.ⁱⁱ

The second section offers insights into some of the ways in which geographers have historically engaged with neuroscience and cognitive science, drawing particular attention to the novel political challenges posed by human geography's more recently identified 'neural turn'. The discussion demonstrates the need for geographers to advance understandings of the rationale for and unintended consequences of a global appeal to neuroscientific explanation within public policy and practice.

This policy enthusiasm for neuroscientific and behavioural science insights has been global in reach (e.g. Dolan et al., 2010; van Bavell et al., 2013; White House, 2013; World Bank, 2015). It is at play in contemporary governance strategies which are informed by behavioural science, and has been manifest in different spheres of practice including in education, work, parenting discourse, wellbeing policies, happiness economics, health and social care, criminal justice, architecture and marketing (Royal Society, 2011; Pykett, 2015; Whitehead et al., 2017). In its account of what a 'critical neuro-geography' might offer, the paper argues that analysis of the *situatedness of subjectivity* is essential for unpacking the political implications of neuroscience and cognitive science research as they are transferred from laboratory experimentation to inform policy and practice (though the boundaries of

the laboratory are being blurred, as the paper will explore). Exploring the situatedness of subjectivity provides a substantive grounds for establishing dialogue with cognitive and neuroscientists to problematize and enrich dominant understandings of human consciousness, behaviour and action in ways which are sensitive to existing spatial inequalities, social differences, relationships between different scales and issues of power and governance.

Geographical trends in the neurosciences

Cognitive scientists have not, to my knowledge, engaged with geographical literatures, apart from a few papers which refer to geographical information systems (e.g. Louwerse and Zwaan, 2009). Yet geographical concepts are frequently implicitly adopted by cognitive scientists and neuroscientists, including within debates around the value of 'localization' of cognitive phenomena, to processes of spatial and environmental perception (including the importance of situations in determining behavioural responses), and distributed, embodied accounts of attention and cognitionⁱⁱⁱ. Taking these three broad geographical trends as starting points, this section outlines some of the geographical assumptions debated within contemporary cognitive science and neuroscientific research in order to sketch out the future potential for a more substantive engagement between geography and the neurosciences.

Localization and brain geography

'Mapping the brain' has arguably been one of the main achievements and endeavours of neuroscience over the past 150 years, although the value and politics of this mere 'brain geography' has been questioned by neuroscientists themselves (Taylor 2012: 34).

Neurologist, David Ferrier provided some of the first maps of brain function in the 1870s from animal experimentation and work with criminals and in Victorian mental asylums (Rose and Abi-Rached, 2013: 64). Others had already begun to define the central components and structures of the brain, through the identification of the neuron by Santiago Ramón y Cajal, in the 1890s, and early explorations of neural networks. These insights have had lasting effects, for instance, within recent ongoing efforts to map neural connections under the rubric of Connectomics (Sporns et al., 2005). The establishment of the disciplines of neuroanatomy, neurobiology and neurochemistry during the first half of the 20th Century (Rose and Abi-Rached, 2013: 32), and later innovations in neuroimaging techniques have concentrated the imperative to search for particular sensory and motor functions within specific brain regions or locales, and to identify cognitive processes strictly with the biological, chemical and physiological features of the brain. fMRI technologies and EEG methods, amongst others, have enabled neuroscientists to produce visual maps of the brains of living organisms including the human brain, further enhancing the quest for cerebral localization.

As one would expect, cognitive neuroscience is not a univocal venture; there is debate over the value, accuracy and contextual transferability of brain localization within neuroscience in general and neuroimaging research in particular (e.g. Brett et al., 2002). The cognitive neuroscientists interviewed recognized the specific scalar assumptions made through neuroimaging research or research on narrowly defined facets of human perception,

memory, attention or behaviour. While they might have been indebted to advances in neuroimaging techniques, they were equally cautious of their seductive appeal and aware of the limitations of the findings afforded by such methods:

“So when the scanners first became sort of usable for cognitive neuroscientists it was, like, you know, a kid in a candy shop, you just didn’t know what to do first. And then a few years later, that was starting to be viewed as, sort of, brain geography, in a sense, you know, like OK that area’s active and this area’s active, but the brain never works by activating one area, it’s always a composite.” *Cognitive Neuroscientist A, interviewed June 2013.*

Identifying the restricted view of brain localisation, one neuroscientist warned against the over-specialisation associated with career trajectories in neuroimaging, highlighting a certain occularcentrism within neuroscience which can narrow research focus and overemphasise the explanatory purchase of ‘the brain’:

“Most people that specialise will miss the big picture, yes because the brain... because they just focus on their little topic... some people will say there are modules in the brain and each module is specialised in a specific stimuli type or specific processing type and we can know that and we can investigate that. Then they’re just *zooming into that region* and try to understand it, but I think the paper [we wrote] was, kind of, saying by saying that you’re already giving an answer to...which you, you know. They already presume their answer...” *Cognitive Neuroscientist B, interviewed September 2013, emphasis added.*

The methodological presumptions of brain localization here are reminiscent of what Gillian Rose (1995: 762) famously described as the “dominant masculine subject position in the West” associated with spatial mastery, control and surveillance. Whilst Rose was critiquing the spatial *distancing* achieved by visualised space, here we see that ‘zooming in’ can equally serve to obscure the power relations and scientific protocols implicated in localized brain visualizations. Such visualizations prescribe human subjectivity and narrow the available scope and scale of explanation available to cognitive and neuroscientists.

In contrast, a social neuroscientist did not believe that localization should be considered a problem, as long as this is complemented by a more holistic analysis of the brain and is proportionate to the complexity of the behaviour being studied:

“Well I mean I don’t think there’s anything fundamentally wrong. It’s clear from studies in humans and animals that there is a localisation of function in the brain. That’s not really a debate in my mind but it’s certainly not as simple as region x does this and region y does this, functions appear to be distributed in networks and we are not at the point where we fully understand how all of that works, especially for the more complex kind of behaviours that I’m interested in like social behaviour.”

Social Neuroscientist C, interviewed June 2013.

And yet it is clear that the same neuroscientists approach the brain as the ultimate source of our behaviour, and tend towards self-avowedly reductionist accounts of human activity

which are necessary limited in terms of their scale of explanation to the brain as an engine of both behaviour and consciousness:

“because ultimately the mind does arise from the brain, and the brain produces behaviour and you know the contents of the mind, emotions, cognition are what we sort of experience as being causal for behaviour”. *Social Neuroscientist C, interviewed June 2013.*

“I’m a reductionist so I don’t think that there’s anything different about my thinking about politics than it’s thinking about reaching for my cup of coffee, except it just may involve many more steps of reasoning” *Cognitive Neuroscientist A, interviewed June 2013.*

These remarks suggest that there remains a residual adherence to some quite reductionist ideas about localisation and thinking within cognitive science. More ecological approaches which consider the brain *in situ* and in relation to their environment address this reductionism, as the following sections explore.

Spatial and environmental perception

The ecological approach to psychology has a long history. From the 1940s, psychologists such as Kurt Lewin, Roger Barker and Herbert Wright argued that the environment should be considered as the primary determinant of behaviour and developed ‘psychological-habit maps’ to demonstrate this process (Wicker, 1979, cited in Pykett, 2015: 48). Through their observations of behavioural patterns in particular settings, such researchers set out to establish the environmental causes of behaviours rather than reduce social problems to

individual pathologies. But their research was not adopted by mainstream psychology, which has long been concerned with a more spatially-bounded interest in environmental perception. Most psychologists continued to conceptualise the environment as an immediate and literal phenomenon rather than as a multi-layered and multi-scalar ecological system in which behaviour was shaped.

This proximate sense of environmental or spatial perception was integral to the establishment of early modern psychology in the late 1800s. Writing in the 1870s, Hermann von Helmholtz was one of the first to adopt natural science methods to study the physics of the mind – in distinct contrast to Kant’s account of the mind as normatively separate from nature (Hatfield, 2003: viii). Helmholtz’s empirical psychology underpins contemporary cognitive science conceptions of how the exterior world ‘gets inside’ the mind through processes of attention, perception, memory and learning. It is also reflected in the assertion by famous scientists and philosophers that consciousness is reducible to neural processes (Francis Crick; Patricia Churchland, cited in Noë, 2009: 5; 189*n*). Spatial perception remains a research priority within cognitive science, incorporating the visual, auditory and sensorimotor aspects of human interactions with their immediate and proximate environment. While this may provide important insights in terms of the particular actions being studied, the implications for complex forms of social and interactive behaviour are less well developed. As one cognitive neuroscientist described, their research on attention was specifically *functional*, proximate and immediate. Consequently the validity of adopting the same approach for addressing the use of a coffee cup as for political thought becomes far from clear:

“So in particular my interest is in attention, which is a process of, you know, as it’s colloquially defined of focusing on a particular input source so, you know, in this room now there’s lots of different visual stimuli, there’s different auditory stimuli so attention is then a property of the brain that allows you to concentrate on one particular source of many different inputs, so you can expect something to occur over there and you can focus your attention to that source, or you can be wanting to focus on the auditory modality versus the visual modality. And then that intersects in, so the information processing stream with what we call working memory, which is that sort of very brief storage of information that you're acting on at that particular moment in time” *Cognitive Neuroscientist A, interviewed June 2013.*

Meanwhile, studies of environmental perception have developed much more in concert between psychologists and geographers since the 1980s, but have also remained rather wedded to the micro-scale of human-environment interaction, as explored in the section on ‘Human-environment interactions’ below.

Distributed and embodied cognition

A third field of development in cognitive science which partly reflects the same emphasis on the materiality of the mind is the area of distributed, embodied, extended or situated cognition. As with notions of spatial and environmental perception, there is a shared concern for understanding human-environment interaction. But unlike the endeavours of localization and brain geography, it considers cognition itself more as an ecological system distributed between the organ of the brain, the mind and body of the person and the socio-technical environment than as property internal to the cranium. Philosopher Andy Clark

(1999) has recounted a movement within cognitive science towards embodied accounts of the mind in response to the persistent mind-body dualisms pursued by much psychological and neuroscientific research. Others have focussed on the anatomical specificity of human vision and its relation to the environment (e.g. Proffitt 2006), on the relationship between human intelligence and context (Sternberg and Wagner, 1994) and on cognition as a dynamic “brain-body-environment system” always oriented towards specific actions (Wheeler, 2005: 11). Clark has noted the restricted spatial imagination of narrowly materialistic accounts of the brain as: “the space of the inner neural machine, divorced from the wider world which then enters the story only via the hygienic gateways of perception and action” (Clark 1999: 5). Such authors have promoted an alternative cognitive science where “[t]he mind itself [...] is best understood as the activity of an essentially situated brain: a brain at home in its proper bodily, cultural and environmental niche” (Clark, 1999: 5).

Evidence for this strand of thinking within cognitive science is found in studies which, for instance, challenge the ‘input-processing-output’ model of human cognition, showing instead that “daily agent-environment interactions” often do not require full inner representations of the perceptual scene, can rely instead on motor routines, and that actions themselves play a crucial role in cognitive processes (Churchland et al., 1994 cited in Clark, 1999: 8). Clark notes how this account recollects the interactivist notion of ‘affordances’ provided by ecological psychologist, J.J. Gibson, whereby objects or environmental conditions offer up certain courses of action for people.

The idea of affordances was helpfully described by one of the neuroscientists interviewed, whose research involved designing a computer-assisted environment to support stroke patients with executing everyday life tasks such as making a cup of tea. Coasters were designed to sense what the patient was doing and feed this information back into a dynamic system which would alert the person on how to complete the task. Neuroscientific methods and eye-tracking devices were used to understand how young people versus stroke patients looked at objects and made errors in object selection:

“so there is coaster on the mug, there is coaster on the kettle, there is coasters on the milk jar, there are coasters all over the place. So, these coasters send information to a computer and in addition, we’re using, kind of, X-box connection to basically record what’s happening with your upper limb and all this information is fed into a computer to identify what you actually did. Did you add tea bag? Did you add sugar? Did you add water? Did you boil the water? Then, the computer basically tracks what you’ve done and what you should have done and what you are doing. Then based on that, gives you a feedback, ‘Oh you forgot to boil the water. Please boil the water. You didn’t add a teabag, you didn’t add sugar.’” *Cognitive Neuroscientist B, interviewed September 2013.*

This suggests that some cognitive neuroscientists – not necessarily by intention – seem to be adopting a dynamic, embodied and distributed sense of cognition, here in the case of translational health research. Just how far they would stretch this sense of distributed cognition, both metaphorically and literally, would be an interesting starting point for a critical neuro-geography.

Why do brain localization, theories of spatial and environmental perception and a distributed and embodied account of cognition matter beyond the disciplinary confines of cognitive science? These approaches tend in the final analysis towards a reductionist notion of space and context limited respectively to the brain, the perceptual environment or proximate situation, and action-oriented taskscapes. Their value to normative and political discussions (rather than coffee cups), might at first glance appear far-fetched. Up to this point this paper has provided little sign, for instance, of any potential confluence between concepts of space perception deployed in cognitive science and notions of 'spatiality', including concerns of spatial difference, spatial justice, spatial inequality, or spatial politics already well established in human geography. Yet it is precisely a set of distinctly *political* claims which have been advanced through geographical engagements with the cognitive and neurosciences. The next section therefore considers the broader implications of the aforementioned trends by offering a synoptic review of three trajectories in the development of human geography where engagements between cognitive science, neuroscience and geography have been central.

Geographical engagements with the cognitive and neurosciences

There has already been substantial critique of the cognitive and neurosciences by sociologists, cultural theorists, philosophers, psychologists, science and technology studies and medical humanities scholars, who have tried to re-situate the human subject in their behavioural 'milieu' (Rose and Abi-Rached, 2013). Specifically they have identified the

geo-historical circumstances of the emergence of ‘cerebral subjectivity’ (Ortega and Vidal, 2009) and addressed the apparent ‘neuromania’ characterising popular culture (Legrenzi and Ulmita, 2011; Pickersgill et al., 2011; Thornton, 2011; Choudhury and Slaby, 2012; Canter and Turner, 2014; DeVos and Pluth, 2016; Pitts-Taylor 2016). In a more ‘embracing’ fashion, neurophenomenology and neuroanthropology have emerged as approaches which use neuroscientific frameworks and methods to explain experience and consciousness (in the case of neurophenomenology (Varela, 1996)), and the evolution of culture (in the case of neuroanthropology (Duque et al, 2010)). Adding to this field, as reflected in the section on ‘Contextual rationalities’ below, geographers have begun to take a critical interest in the contemporary social and political significance of neuroscience. They have also analysed ‘brain culture’, referring to the influence of neuroscientific insights on a broad spectrum of social practices, processes of subjectification, and public policies (Fitzgerald and Callard, 2014; Gagen, 2015; Pykett 2015). In this section I consider what geographers’ historical engagements with cognitive science teach us about the extent to which a future neuro-geography might embrace or critique the neural turn evident within the social sciences and humanities.

Three areas of human geographic thought are summarised here, selected for what they can each distinctively tell us about integrating cognitive and neuroscience research into our social and spatial explanations of subjectivity, behaviour and context^{iv}. The dynamics of *human-environment interactions* (informed by behavioural geography and environmental psychology), *affective architectures* (as conceived by non-representational theory (NRT)) and *contextual rationalities* (the focus of Foucauldian approaches) are elaborated as setting off points for a critical neuro-geography which is informed by but not indebted to cognitive

and neuroscience insights. The novelty of this approach is to combine (a) the problematisation and enrichment of the geographical concepts deployed and developed in cognitive and neuroscience, with (b) a critical analysis of assumptions concerning political agency found within the global enthusiasm for neuroscientifically-informed public policy and everyday practice, as geographical trends themselves^v.

Human-environment interactions

As already noted, the study of spatial and environmental perception was central to the development of environmental and ecological psychology as branches of cognitive science. Within geography, behavioural approaches became an integral part of the discipline's history from the 1960s. Scholars such as Wolpert, and Golledge and Stimson (cited in Pykett, 2015: 45) explored the relationship between images, revealed perceptions and behaviour, and modelled the way in which minds process information about the environment. Amongst their achievements were their promotion of space as more than simply a surface on which human behaviours were mechanistically played out and their problematisation of 'rational economic man' through developing notions of bounded rationality. Yet blind spots in behavioural geography were being widely criticised by the 1980s: Marxist geographers argued they that offered no real explanation for the structural contexts of human behaviour; humanists felt they disregarded the cultural mediation of human consciousness (Cox, 1981; Ley, 1981 cited in Pykett, 2015: 45). From a psychoanalytic perspective, they were criticised for their gender blindness, for decoupling the mind and body and for providing no conception of the situated processes of subjectification (Pile, 1996). As such, there could be little appreciation within the behavioural approach of the diversity of human

perception and experience, which limits the potential of the behaviourists to appreciate both the hierarchical categorisation (and governance) of different experiences of consciousness, and what is now termed 'neuro-diversity'; valuing and seeking equality for a range of neurological differences in terms of naturally occurring genetic variation.

Despite these significant criticisms, explorations of behavioural geographers of theories of cognition have been developed by the contemporary field of environmental psychology, an increasingly influential field of study which informs public policy debates concerning the interrelations between the environment, mind and behaviour. Devine-Wright and Clayton (2010: 267) have argued that environmental psychology should better re-connect the self and the social by attending to the dynamic relationship between identity, cognition, affect and behaviour, as well as the structural conditions in which people might live more sustainable lives. The hitherto limited engagements of environmental psychologists with issues of social and spatial context pose particular limitations for attempts to analyse the productive effects of cognitive science as applied in policy, which mobilises these very environmental psychological knowledges in order to shape citizens' behaviours. In seeking to render measurable psychological 'traits', attitudes, and values, and in its ambitions to operationalise workable models of behavioural change, what gets left out of many such studies is consideration of the specific mechanisms through which human subjectivity is itself socially and spatially produced in specific contexts. These blind-spots also plague the behavioural turn in public policy and governance evident in the work of 'nudge units' now operating in governments across several nation states (Whitehead et al., 2017).

Affective architectures

Since the late 1990s, human geography has seen a discernible ‘neural turn’ through the development of Non-Representational Theory (NRT), which is partly founded on neuroscientific explanations of human action (Korf, 2008). At the same time geography has become more sensitive to materiality, the agency of non-human actors and to bodily practices in general. NRT has drawn on distributed accounts of embodied cognition offered by cognitive science, and in the environmental affordances of particular spatial arrangements (Thrift 2008; Anderson and Harrison, 2010: 7). NRT argues that practices, events and relations are best understood outside of systems of representation (structures of writing, language, conscious expression, interpretation, social constructs). This approach is ‘bio-social’ in that it proposes that the individual, atomistic, rational self is a modernist fiction and Cartesian error, and that we need to develop a new performative style of thinking concerning human nature and the subject. The influence of neuroscience can be traced within Deleuzian strands of NRT in geography, as evidenced by Deleuze and Guattari’s materialist and embodied conceptualisation of the brain as a site of the “resolution of forces” within which the radical multiplicity of the world is selectively perceived, abstracted and creates new possibilities for thought (Watson, 1998: 29; 34). For geographers such as McCormack, for instance, an attention to the molecular, including neurochemistry is pertinent to developing a human geography which attends to the way in which thinking itself “emerges from a sensible field”, is material, and constituted in dynamic relation with the world and the non-human (McCormack 2007: 365). There are specific traces of affective neuroscience evident in this strand of human geography, with reference to Joseph Le Doux, Francisco Varela and Antonio Damasio being prominent. Yet there is surprisingly little discussion of cognitive neuroscience and social neuroscience in this work.

This selective interest in certain strands of neuroscience, as Papoulias and Callard (2010) have pointed out, explains why the NRT approach is able to claim a neuroscientific basis for its generative or performative politics within fields of seemingly infinite possibilities whilst apparently ignoring the often explicit determinism and reductionism of other neuroscience strands, as we shall see later.

One of the founding tenets of NRT is based in contemporary neuroscientific accounts of personhood; that human action *precedes* cognition; put simply, we act *before* we think. It is this insight that leads Thrift to assert a radically new spatial politics of affect based on the frailty of decision-making and psychological challenges to the illusory notion of free will:

‘Wundt was able to show that consciousness takes time to construct; we are ‘late for consciousness’ (Damasio 1999: 127). That insight was subsequently formalized in the 1960s by Libet using the new body recording technologies. He was able to show decisively that an action is set in motion before we decide to perform it: the ‘average readiness potential’ is about 0.8 seconds, although cases as long as 1.5 seconds have been recorded. In other words ‘consciousness takes a relatively long time to build, and any experience of it being instantaneous must be a backdated illusion’” (Thrift, 2004: 67).

Thrift thus takes up Libet’s findings to argue that the “constantly moving pre-conscious frontier...is highly political”; a sphere of “*microbiopolitics*” (Thrift, 2004: 67). Because it has become visible to science, this moment between action and consciousness awareness can be targeted and operated on by various actors in order to produce particular political

responses. This is particularly the case in urban design, which Thrift identifies as a new political field in which affective responses can be effectively pre-programmed and as the broad means by which *affective architectures* can be engineered (Thrift, 2004: 68). In positing the post-human subject as the key actor (that we can never be separated from our environments), NRT points towards the “insufficiency of argument” as a political *modus operandi* (Thrift, 2004: 71). The political subject posed here is diminished to a figure drowned out by its affective capacities and pre-figurative neural drivers, who is fooled by their own post-hoc rationalisations for action. This neurally-inflected citizen, determined by their biology to act in non-rational ways, is susceptible to affective forms of manipulation.

NRT and its related spatial politics of affect have not entered the discipline of human geography without criticism. For some, the non-representational approach is based on a highly deterministic attack on the rational modernist subject, which relies on the naïve naturalism of presuming that localized brain processes *cause* human action rather than on convincing critiques of this false universality (Korf, 2008). This is relevant here insofar as brain culture and its associated global policies and everyday practices rely heavily on the claim that we can no longer be understood as rational actors. For Korf (2008: 716), there is no space left by NRT to address the contingency of subjectivity (its relation to context) rather than its determinacy. Others have broadly challenged its reliance on partial narratives of neuroscience and cognitive science, which have been anchored to a biological account of personhood and thinking which remains deterministic and evolutionarily ‘set in’ rather than shaped by context-specific processes of embodied subjectivity (Papoulias and Callard, 2010: 34). The political insights offered by NRT are further problematized by debates within cognitive neuroscience and beyond around the validity of Libet’s original

experiments and assumptions. Tallis (2011: 247) points out that Libet's inattention to context led him to the flawed and troubling denial of free will, precisely because the experimental set-up itself reduced the concept of free will or human action to a narrow bodily movement (flexing the wrist) which could then be measured in relation to brain activity. "It is no surprise" observes Tallis "that we cannot find free will in this isolated moment in a laboratory, if we treat it as an isolated moment" (2011: 250).

Geographers have expressed substantial scepticism towards the political ramifications of NRT's engagements with neuroscience, in particular its insistence of the primacy of affect over emotion, rationality, intention and deliberation (Barnett, 2008; Pile, 2010). As such they have criticised how NRT celebrates the creative politics of affect (the radical possibility of the biological brain-world continuum to generate new concepts, thought and action), whilst conversely decrying the susceptibility of affects to be engineered by the powerful (Pile, 2010: 12). It has been argued that both Thrift and cultural theorist, William Connolly (2002), who is referenced at length by Thrift, render a version of *neuropolitics* as the manipulation of affects by mood manipulators and affective architects. The very possibility of thought is said to be scripted by culture (Connolly, 2002: 94), and only a Deleuzian-qua-neuroscientific account of the layered "geology of thought" (Connolly 2002: 90) is sufficient to expose the "affective organization of thought and judgment" (Connolly 2002: 94). Barnett (2008: 189) draws on pragmatist philosophy to argue against this ontological layering of the practical priming of action by an environment to which the body/brain is attuned, as preceding (and prioritised over) language, intention, representation and expressive rationality. In other words, Barnett (2008: 190) rejects NRTs notions of the affective governance of public space and its suspicion of both engineered affects and

deliberative forms of democracy. Instead, he points us towards work in political science which has long established the central role of affect and non-rational feelings in political deliberation and encountering others. Unlike the apparent universalism of NRT, it can be argued that this kind of approach better accounts for social difference and retains a space for expressed argumentation and justification – as Barnett (2008: 190) terms it, the “giving and asking for reasons”.

Yet while we may want to question the “layer-cake interpretation” and “logical geography” of human action provided by NRT, a critical neuro-geography might well build on Thrift’s important search for the ‘whereabouts’ of subjectivity. As such, geographers might focus on “sites at which behaviour was modified, that is with the moment, the location, and the mechanism through which difference or invention was produced” (Thrift, 2008: 84). In this way, the more spatial engagements of NRT with theories of distributed cognition (Thrift, 2008) could act as a valuable challenge to the tendency within some strands of neuroscience to locate human consciousness and thereby, human subjectivity narrowly in the brain. This is also evidenced in Anderson and Harrison’s (2010: 286) nuanced reading of the scalar imaginations and political activism of Guattari, which are in stark contrast to the emphasis on micropolitics and cultivating techniques of the self, including meditation, mystical, body and ritual practices proposed by Connolly (2002: 100-102) and Thrift (2008: 65-6). As the following section argues, a concern with the *whereabouts/situatedness* of subjectivity, the *scalar politics* of the cognitive, social and affective neurosciences, together with Foucauldian accounts of the rationalities of action and disposition of things offers productive common ground for geography and neuroscience.

Contextual rationalities

Within recent geographical thought there appears to be an ongoing impasse between approaches focussed on the non-representational, pre-cognitive domain of affective practices, and those centred on the discursive contexts in which bodies and subjects are socially differentiated as gendered, classed, racialized, (dis)abled, sexualised, aged and so on (e.g. Tolia-Kelly, 2006). Foucauldian analyses of discourse have had a sustained influence on geographical critiques relating to the truth claims of various forms of psychological, cognitive science or neuroscience knowledge, and their deployment through techniques of governing, ethical practices of self-making and subject-formation. In this sense, for a critical neuro-geography, cognitive science is more the *object* of study than the means by which to account for human-environment relations. For Gagen (2006; 2015) and Pykett (2013; 2015), Foucault's work foregrounds the constitutive role of discursive rationalities in shaping the (unequal) contexts in which human action and subjectivity are shaped, emphasising interplays of power and knowledge through what he famously termed the 'conduct of conduct'.

Rather than denoting a proximate, material ecology of perception and action, the notion of *context* here refers to specific spaces, the discursive qualities of those spaces as cultural milieux, and the ways in which those spaces are always already shaped by governmental practices. In this light, context can be understood as a geo-historical epoch which renders certain courses of action and subject positions possible. Gagen, for instance, emphasises how child development theories and child-study tests in American schools at the turn of the 20th Century signified the absorption of psychological knowledge into spatial practices, in ways which conflated the moral, mental and physical attributes of children:

“As interiority was systematically brought within the realm of science and reconceptualised as material, the traditional metonymic connection between physicality and morality dissolved into a new material relationship between the self and its numerical existence” (Gagen, 2006: 829).

More recently, she has described how contemporary interest in neuroscientifically informed emotional education in UK schools reimagines education in light of the demands of the neoliberal workplace and its demand for social and emotional ‘competencies’ (Gagen 2015). Similarly, Pykett (2015) has highlighted how a brain-based spatial rationality has informed both the ‘neuroarchitectural’ design of schools and the adoption of neuroeducational methods, in a way which reaffirms an agenda of economic competitiveness, responsabilization and self-optimization.

Rationalities, in turn, refer to the truths, thoughts or knowledges which imply the aims of government (Huxley, 2006: 772), where a “regime of rationality” serves to “found, justify and provide reasons and principles for these ways of doing things” (Foucault, 1991 in Huxley, 2006: 771). In this way, Callard and Fitzgerald (2015: 99-100) have described how a Foucauldian notion of power as a technique of categorization also shapes efforts to foster interdisciplinary engagements between social scientists and neuroscientists – warning of the “[r]hetorics of reciprocation and mutuality” which underpin such efforts despite clear disciplinary hierarchies in terms of both financial power and epistemological currency.

Foucauldian geography can help us to understand the regulation and governance of human subjectivity at both the scale of the body (*anatomo-politics*) and whole populations

biopolitics) in ways that do appreciate fleshy materialities, vital bodies, the non-textual, resistive practices and embodied difference (Philo, 2012: 499; 505). This work reminds us that all human action is governed through the arrangements of space, the orchestration of relationships, the management of populations and cultivation of the self. This fact does not imply that we are all somehow being manipulated but rather that we live in social environments shaped by history and geography in which the liberal conception of autonomy is an Enlightenment construct (Crawford, 2015: 120). In this sense we are compelled to consider the socially and spatially uneven and unequal landscapes within which human action takes place rather than to endlessly cogitate on the possibility or otherwise of autonomous thought.

One way in which the contextual rationalities approach can be developed is through an emphasis on the politics and economics of attention. This could pave a path through the above debates in order to advance a critical neuro-geography fit to communicate the potential value of geographical research to cognitive and neuroscientists (since interdisciplinary conversations have been decidedly one-way thus far). Geographers (e.g. Scott 2008) have recently explored the terrain of ‘cognitive capitalism’ (Lazzarato 1996; Boltanski and Chiapello, 2007; Vercellone, 2005) in order to understand the political significance of contemporary shifts towards a knowledge economy, state concerns to improve cultural and psychological capital, and the forms of immaterial, affective and emotional labour implied therein. So too they have considered the “attention economy” implied by these shifts which has been re-organised by the cultural and technological characteristics of the contemporary Western informational, mediated and digital era (Crogan and Kinsley, 2012). Geography can provide an integrative analysis of the contextual

rationalities of these perceptual environments which is at once sensitive to embodied cognition and the longer-running geo-historical shifts implicated by the governing of subjectivity and the conduct of conduct.

There are emergent examples of what this kind of analysis looks like. For instance, Matthew Hannah (2013: 235) – informed by Foucauldian interpretations and a politicized phenomenological philosophy – has provided an original historical account of the emergence of “constructions of modern perception” in order to critique the uneven landscapes of attention shaped by contemporary capitalism. Unlike Connolly’s *neuropolitics*, which focuses on the apparent crisis of distraction and the need for cultivating meditative techniques of the self, Hannah concentrates on “the finite embodied availability and the *directional selectivity* of attention” (Hannah, 2013: 235, original emphasis). He sets out a political economics of attention, which unlike the non-representational approach locates the source of political agency firmly in our subjective human capacities for deliberation and reflection as opposed to the neurobiological frontier between action and cognition. His account is also contextualised in a specific geo-historical epoch. Similarly, Callard and Margulies (2011) have examined how the *state of attention* itself has been colonized through neuroscience. They demonstrate how the ‘brain at rest’ (the so-called default or ‘resting state’ brain which forms the contrasting baseline for neuroscientific studies of brain ‘activity’) has been re-imagined as a productive site of industriousness, creativity, future strategizing and purposeful mind-wandering. As such, it is indicative of the “often unacknowledged isomorphism between models of the brain and models of socio-economic organization” Callard and Margulies (2011: 245).

These arguments hint towards a further basis for productive engagement between NRT and Foucauldian approaches to a critical neuro-geography, where the situated subject is understood within both her specific ecology of attention and within particular contextual rationalities. In other words, this approach investigates both affective architectures and forms of expressive rationality, deliberation and judgment. We might therefore study the role of cognitive science and neuroscientific knowledge in shaping spatial forms in two parallel senses. Firstly, through a consideration of the affordances of spaces, landscapes and environments, the necessarily finite capacities of the human body to be affected and its distributed sense of agency. And secondly through a sensitivity towards the power dynamics and 'directional selectivity' of attention for which understanding the historical materialisms and discursive formations of uneven and differentiated capitalism, as well as first-person expressed experiences of space are essential. The conclusion will spell out why this might provide useful grounds for future geographical dialogue with cognitive scientists and neuroscientists.

Conclusion. For a critical neuro-geography

There is by now established evidence of dialogue between behavioural scientists, cognitive neuroscientists and policy makers informing policy strategy. There are numerous examples of applications of the neuro-prefix in setting both new research agendas and in fields of practice as diverse as workplaces, urban design, education, criminal justice and health. Such is the extent of this influence that commentators have been compelled to ask searching questions about the political, economic and cultural ramifications of this global venture. Seymour and Vlaev (2012: 449) have asked: "can, and should, behavioural neuroscience

influence public policy?” Will Davies has asked how the appeal to psychological and biological explanation has been allowed to bypass moral and political debate (2015: 20). Others have looked at phenomena such as neuroeconomics and neuromarketing, and demanded to know: “why is this form of reductionism rampant at this point of our history?” (Schneider and Woolgar, 2012: 185). Indeed as the paper has indicated, a significant corpus of neuro-criticism has emerged in response to what has been heralded as the incremental rise of brain culture, highlighting the potential diminution of personhood, agency and personal and political attention conferred by neuroscience-society relations.

The emergence of brain culture requires scrutiny of the uses to which psychology, behavioural science and cognitive science have been put in framing problems and proposing solutions to a whole raft of social, economic and governance issues. The paper has proposed that such scrutiny is enhanced by the perspective of a critical neuro-geography: an interdisciplinary engagement between cognitive science, neuroscience and human geography. This engagement draws on the critical purchase of human geography in at least three ways. Firstly, it examines the transferability of geographical concepts as deployed within the cognitive and neurosciences, in order to problematize and enrich the definitions and assumptions made therein. Secondly, it learns from past engagements and the degree to which they have embraced or problematized shared concepts and concerns, and in terms of their partial/selective uptake of neuroscientific insights. Thirdly, it sets out to identify and explain the spatially uneven effects of brain culture, taking into account the material, embodied and discursive contexts in which neuroscientifically-informed social practices, political agency and public policies are assembled, shaped and sustained. Critical neuro-geography builds on approaches within psychology and neuroscience which have recently

highlighted the ways in which reflexive human experience is historically and geographically contingent; namely 'critical psychology' (Parker, 2015) and 'critical neuroscience' (Choudhury and Slaby 2012).

A critical neuro-geography should be informed by but not indebted to neuroscience and cognitive science. It recognises the necessary partiality of both disciplinary perspectives, in terms of their accounts of human perception, attention, behaviour, subjectivity and action. A critical neuro-geography offers new insight into the sources of this partiality, assessing distinguishing features, common ground, advancing complementary approaches where possible, and challenging assumptions where necessary. As the first section outlined, at heart the disciplines of geography and neuroscience operate at different scales of explanation, relying on quite distinct conceptualisations of localization, scale, context, situation, environment, space and distributed cognition/agency. This matters because these conceptualisations imply wildly contrasting explanations for contemporary social, economic and governance problems, and connote entirely different sources of human consciousness and political agency.

The drive towards localization and brain mapping has withstood extensive criticism from both within and outwith the cognitive sciences, although serious differences in the validity of localisation, reductionism and the propensity for brain visualisations to obscure the 'big picture' are evident from the research interviews presented in this paper. This suggests that geographers could play a useful role in extending the research site of cognition (and supposed source of behaviour) along a scalar continuum from brain activity to human action in real-world contexts. So too, geographers can highlight the political rationalities of

mapping, and both the interiorisation and spatialization of moral and political norms, as shown by Gagen's work. This foregrounds the historical and geographically specific contexts in which human action is shaped not only by perception, attention, memory, learning, enaction and affective capacities – but also by enduring conditions of inequality, social difference and subjectification, power struggles over recognition, and spatially and socially uneven material and discursive capacities for action.

Relatedly, geographers can improve the sometimes basic conceptions of 'the environment' as portrayed by researchers of spatial and environmental perception (and arguably also within social neuroscience). Too often 'the environment' is defined in this work in terms of the microscale attentional environment, the immediate perceptual moment, or the characteristics of the social group to which research subjects are immediately exposed (here a social group maybe by human or animal, suggesting that such an approach may be ill-equipped to deal with complex social structures such as capitalism, for instance). As the paper has outlined, recent debates in environmental psychology suggest ways for breaking out of the behaviourist mould by bringing issues of culture, difference and social context into view. In distinction, NRT approaches in geography have sought to divert attention away from the dynamics of cultural inscription or social construction, looking directly to neuroscience to highlight the importance of the pre-cognitive and affective realm in shaping human thought and experience. As a branch of geography which draws most clearly from neuroscience, in particular from accounts of embodied/distributed cognition and affective/emotional neuroscience, this perspective should be taken seriously. But in looking to neuroscience to establish a radical political project based on the generative potential of the embodied brain, this approach has been criticised on several counts: firstly, for its

troubling attitude towards free will and its resultant foreclosure of the ethical human agent and practical reason; secondly, for its ambiguous account of the possibilities of subliminal political manipulation through affective architectures; and thirdly, for its dismissive stance towards the constitutive power of social and cultural representations in constituting differentiated subjectivity. Indeed this venture marks some of the dangers of attempting to transfer concepts outside of the scientific laboratory.

Throughout these engagements, the impetus has been to incorporate cognitive and neuroscience perspectives into geographical study. By contrast, Foucauldian geographies have approached the neurosciences as an object of study as opposed to a means of analysis. As such this has arguably provided a more comprehensive demonstration of what a critical neuro-geography could contribute to advancing new dialogues with contemporary cognitive and neuroscientists. Its potential lies in particular in how it addresses the contextual rationalities of human attention, perception and conduct by attending *both* to embodied, enacted notions of cognition (and pre-/non-cognition) *and* the broader geo-historical contexts in which uneven ecologies of attention are shaped, subjectivities are situated and people are governed – at a number of relational scales. Its interests in the role of neuroscientists as an epistemic community invoked in the pursuit of increasingly affective forms of governance provides the critical distance that marks it out from the previous neural turn in geography^{vi}. From here, it provides new ground from which to establish dialogue with social neuroscientists who are yet to satisfactorily grapple with issues of social discourse, inequality and difference. So too it could begin to experiment methodologically with neurotechnologies and wearable biosensors outside of laboratory contexts in order to develop a more distinctly geographical perspective on the political economies of attentional

environments. Such a methodological innovation needs to incorporate multiple scales of analysis (and address the relations between them), attend to the inherent relationality between the social, spatial inequality and selfhood, and be mindful of the potential power dynamics and blind-spots conferred by rendering brains and emotions measurable and governable, not to mention the scientific validity of ‘uncontrolled’ real world experimentation.

In sum, a critical neuro-geography offers two novel benefits in terms of understanding the relationship between neuroscience, society and spatiality. First it is able to accommodate the circularity effects of living within a brain culture in which popular discourse, global policy agendas and everyday practices have already been influenced by brain-based explanation – by situating the human subject within their scaled-up context. Secondly it provides a basis for empirical research on particular manifestations of brain culture which takes seriously both the embodied brain and the situated processes of subject formation. As such it calls on geographers to find new ways to investigate differentiated and embodied experience which will sometimes bring together and sometimes strategically hold in tension the biophysical and discursive elements of experience without returning to naïve mind-body dualisms. And it calls on cognitive and neuroscientists to take seriously the historical and geographical ‘real-world’ contexts in which human action is shaped, the potential policy and political implications of their own work, the political rationalities of particular uneven spatial arrangements, the dispositions of things and modes of conduct, and the everyday first-person experiences of these arrangements. Only in this way can we adequately assess the potential consequences of too partial explanations of the value, boundedness and purpose of human behaviour in the context of inequality and difference.

References

- Anderson B and Harrison P 2006 Questioning Affect and Emotion *Area* (38) 333-335
- Anderson B and Harrison P eds 2010 *Taking-Place: Non-Representational Theories and Geography* Ashgate, London
- Barnett C 2008 Political affects in public space: normative blind-spots in non-representational ontologies *Transactions of the Institute of British Geographers* 33 (2) 186-200
- Barr S W and Prillwitz J 2014 A Smarter Choice? Exploring the Behaviour Change Agenda for Environmentally Sustainable Mobility *Environment and planning C* 32 (1) 1-19
- Bermúdez J L 2010 *Cognitive Science: An introduction to the science of the mind* Cambridge University Press, Cambridge
- Boltanski L and Chiapello E 2007 *The New Spirit of Capitalism* Verso, London
- Brett M Johnsrude I S and Owen A M 2002 Opinion: The problem of functional localization in the human brain *Nature Reviews Neuroscience* 3 243-249
- Callard F 2006 “The sensation of infinite vastness”; or, the emergence of agoraphobia in the late 19th century *Environment and Planning D: Society and Space* 24 (6) 873-889

Callard F and Fitzgerald D 2015 *Rethinking Interdisciplinarity across the Social Sciences and Neurosciences* Palgrave MacMillan, Open Access ebook, at:

<http://www.palgrave.com/us/book/9781137407955>

Callard F and Margulies D S 2011 The subject at rest: novel conceptualizations of self and brain from cognitive neuroscience's study of the 'resting state' *Subjectivity* 4 (3) 227-257

Canter D and Turner D A eds 2014 *Biologising the Social Sciences: Challenging Darwinian and Neuroscience Explanations* Routledge, Abingdon

Cacioppo J T Berntson G G Adolphs R et al eds 2002 *Foundations in Social Neuroscience*, The MIT Press, London

Choudhury S and Slaby J eds 2012 *Critical Neuroscience* Wiley-Blackwell, Chichester

Clark A 1999 Where brain, body, and world collide *Journal of Cognitive Systems Research* 1 5-17

Clark G L 2011 Myopia and the global financial crisis: short-termism, context-specific reasoning, market structure and institutional governance *Dialogues in Human Geography*, 1 4-25.

Connolly W E 2002 *Neuropolitics. Thinking, culture, speed* University of Minnesota Press, London

Crawford M 2015 *The World Beyond Your Head* Viking, London

Crogan P and Kinsley S 2012 Paying attention: towards a critique of the attention economy *Culture Machine* 13 1-29

Damasio A Tranel D and Damasio H 1990 Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli *Behavioural Brain Research* 41 (2) 81–94

Davidson R J and Sutton S K 1995 Affective neuroscience: the emergence of a discipline *Current Opinion in Neurobiology* 5 (2) 217–224

Davies G 2010 Captivating behaviour: mouse models, experimental genetics and reductionist returns in the neurosciences *The Sociological Review* 58 (1) 53-72

Davies W 2015 *The Happiness Industry* Verso, London

Devine-Wright P and Clayton S 2010 Introduction to the special issue: place, identity and environmental behaviour *Journal of Environmental Psychology* 30 (3) 267–270

DeVos J and Pluth E eds 2016 *Neuroscience and Critique* Routledge, London

Dolan P Hallsworth M Halpern D King D and Vlaev I 2010 *MindSPACE. Influencing behaviour through public policy* The Institute for Government and Cabinet Office, London

Duque J F D Turner R Lewis E D and Egan G 2010 Neuroanthropology: a humanistic science for the study of the culture–brain nexus *Social Cognitive and Affective Neuroscience* 5 (2-3) 138-147

Fitzgerald D and Callard F 2014 Social Science and Neuroscience beyond Interdisciplinarity: Experimental Entanglements *Theory, Culture & Society* 32 (1) 3-32

Gagen 2006 Measuring the Soul: Psychological Technologies and the Production of Physical Health in Progressive Era America *Environment and Planning D: Society and Space* 24 (6) 827-849

Gagen E 2015 Governing emotions: citizenship, neuroscience and the education of youth *Transactions of the Institute of British Geographers* 40 (1) 140–152

Hannah M 2013 Attention and the phenomenological politics of landscape *Geografiska Annaler: Series B* 95 (3) 235–250

Hatfield G 2003 *The Natural and the Normative: Theories of Spatial Perception from Kant to Helmholtz* The MIT Press, Cambridge, MA

Huxley M 2006 Spatial rationalities: order, environment, evolution and government *Social and Cultural Geography* 7 (5) 771-787

Jones R Pykett J and Whitehead M 2013 *Changing behaviours. On the rise of the psychological state* Edward Elgar, Cheltenham

Kingstone A Smilek D and Eastwood J D 2008 Cognitive Ethology: A new approach for studying human cognition *British Journal of Psychology* 99 317–340

Korf B 2008 A neural turn? On the ontology of the geographical subject, *Environment and Planning A*, 40 (3) 715-732

Kraftl P 2013 Beyond 'voice', beyond 'agency', beyond 'politics'? Hybrid childhoods and some critical reflections on children's emotional geographies *Emotion, Space and Society* 9: 13–23

Lazzarato M 1996 'Immaterial Labour' in M Hardt and P Virno (eds) *Radical Thought in Italy: A Potential Politics*. University of Minnesota Press, Minneapolis

Legrenzi P and Umiltà C 2011 *Neuromania: On the limits of brain science* Oxford University Press

Louwerse M M and Zwaan R A 2009 Language Encodes Geographical Information *Cognitive Science* 33 (1) 51-73

McDowell K Lin C Oie K S et al 2013 Real-world neuroimaging technologies *IEEE Access* 1 131-149

McDowell L 2011 Making a drama out of a crisis: representing financial failure, or a tragedy in five acts *Transactions of the Institute of British Geographers* 36: 193–205

Noë, A. (2009) *Out of our Heads* Hill and Wang, New York

Ortega F and Vidal F eds 2011 *Neurocultures* Peter Lang, Frankfurt am Main

Papoulias C and Callard F 2010 Biology's Gift: Interrogating the Turn to Affect *Body and Society* 16 (1) 29–56

Parker I ed 2015 *Handbook of Critical Psychology* Routledge, London

Philo C 2012 A 'new Foucault' with lively implications – or "the crawfish advances sideways" *Transactions of the Institute of British Geographers* 37 (4) 496–514

Picard R and Healy J 1997 Affective wearables *Personal Technologies* 1 (4), 231-240

Pickersgill M Cunningham-Burley S and Martin P 2011 Constituting neurologic subjects: neuroscience, subjectivity and the mundane significance of the brain *Subjectivity*, 4: 346–365

Pile S 1993 Human Agency and Human Geography Revisited: A Critique of 'New Models' of the Self *Transactions of the Institute of British Geographers* 18 (1) 122-139

Pile S 1996 *The Body and the City* Routledge, London

Pile S 2010 Emotions and affect in recent human geography *Transactions of the Institute of British Geographers* 25 (1) 5-20

Pitts-Taylor V 2016 *The Brain's Body. Neuroscience and corporeal politics* Duke University Press, London

Proffitt D R 2006 Embodied Perception and the Economy of Action *Perspectives on Psychological Science* 1 (2) 110-122

Pykett J 2012 Making youth publics and neuro-citizens: critical geographies of contemporary educational practice in P Kraftl, J Horton and F Tucker eds *Youth Matters: critical geographies of children and youth: policy and practice* Bristol: Policy Press

Pykett J 2013 Neurocapitalism and the new neuros: using neuroeconomics, behavioural economics and picoeconomics for public policy *Journal of Economic Geography* 13 (5) 845-869

Pykett J 2015 *Brain Culture. Shaping Policy through Neuroscience* Policy Press, Bristol

Pykett J and Disney T 2015 Brain-Targeted Teaching and the Biopolitical Child, in K P Kallio and S Mills eds *Politics, Citizenship and Rights*, Vol. 7 of T Skelton ed *Geographies of Children and Young People* Berlin: Springer

Pykett J and Enright B 2016 Geographies of brain culture. optimism and optimisation in workplace training programmes *Cultural Geographies* 23 (1) 51-68

Robbins P and Aydede M eds 2009 *The Cambridge Handbook of Situated Cognition* Cambridge: Cambridge University Press

Rose, G. 1995 Distance, surface, elsewhere: a feminist critique of the space of phallogocentric self/knowledge. *Environment and Planning D: Society and Space* 13 761-781

Rose N and Abi-Rached J M 2013 *Neuro. The new brain sciences and the management of the mind* Princeton University Press, Woodstock

Royal Society 2011 *Brain Waves Module 1: Neuroscience, Society and Policy* The Royal Society, London

Schneider T and Woolgar S 2012 Technologies of ironic revelation: enacting consumers in neuromarkets *Consumption, Markets & Culture* 15 (2) 1-12

Scott A J 2008 Resurgent Metropolis: Economy, Society and Urbanization in an Interconnected World *International Journal of Urban and Regional Research* 32 (3) 548-564

Seymour B and Vlaev I 2012 Can, and should, behavioural neuroscience influence public policy? *Trends in Cognitive Sciences* 16 (9) 449-451

Sporns O Tononi G and Kötter R 2005 The Human Connectome: A Structural Description of the Human Brain *PLoS Computational Biology* 1(4) e42, 0245-0251

Sternberg R J and Wagner R K eds 1994 *Mind in Context* Cambridge: Cambridge University Press

Tallis R 2011 *Aping mankind Neuromania, Darwinitis and the misrepresentation of humanity* Durham: Acumen

Taylor K 2012 *The Brain Supremacy. Notes from the frontiers of neuroscience* Oxford: Oxford University Press

Thien D 2005 After or beyond Feeling? A Consideration of Affect and Emotion in Geography *Area* 37 (4) 450-454

Thornton D J 2011 *Brain Culture: neuroscience and popular media* Rutgers University Press Piscataway, NJ

Thrift N 2004 Intensities of feeling: towards a spatial politics of affect *Geografiska Annaler* 86B 57-78

Thrift N 2008 I just don't know what got into me: where is the subject? *Subjectivity* 22 82-89

Tolia-Kelly D P 2006 Affect - an ethnocentric encounter?: Exploring the 'universalist' imperative of emotional/affectual geographies *Area* 38 213-217

Varela F 1996 Neurophenomenology: A methodological remedy for the hard problem *Journal of Consciousness Studies* 3 (4) 330-49

van Bavell R Herrmann B Esposito G and Proestakis A 2013 *Applying Behavioural Sciences to EU Policy-making* Publications Office of the European Union, Luxembourg

Vercellone C 2005 The hypothesis of cognitive capitalism. London, Birkbeck College and SOAS, UK, at: <https://halshs.archives-ouvertes.fr/halshs-00273641/>

Watson S 1998 The neurobiology of sorcery: Deleuze and Guattari's brain *Body and Society* 4 (4) 23-45

Wheeler M 2005 *Reconstructing the Cognitive World: the next step* MIT Press, Cambridge, MA

Whitehead M Jones R Lilley R Pykett J and Howell R 2017 *Neuroliberalism: Behavioural government in the twenty-first century* London: Routledge

White House 2013 'Psychological Science and Behavioral Economics in the Service of Public Policy. Meeting Summary' at: <https://www.nia.nih.gov/about/events/2013/white-house-workshop-psychological-science-and-behavioral-economics-service-public>

World Bank 2015 *Mind, Society, and Behaviour* International Bank for Reconstruction and Development / The World Bank, Washington

Yalachkov Y Naumer N and Plyushteva A 2014 The compulsive habit of cars *Trends in Cognitive Sciences* 18 (5) 227–228

ⁱ The paper primarily focuses on the cognitive sciences and neurosciences, reflecting a plurality of conceptual and technological developments in the scientific/biological study of the brain which have had an impact within social science and human geography in particular. There is overlap between the cognitive sciences, neurosciences, psychology and behavioural sciences encountered in the paper. I use the term cognitive science to refer to the overarching endeavour to provide a scientific framework for explaining the human mind, its

mental architecture and systems of information-processing (after Bermúdez, 2010: xvii). Within this framework, neuroscience refers to the anatomical and biophysical study of the brain and nervous system. While cognitive neuroscience in turn refers to the neuroscientific study of mental processes (as psychological concepts), there are many other aspects of the human mind including non-cognitive, affective, embodied, social and enactive elements which are not well captured by the term cognitive neuroscience. The paper does not resolve these important and complex debates but forges a specific path through which geographers could tread.

ⁱⁱ The interviews were transcribed and coded using the geographical themes of localization, scale, context, situation, environment, space and distributed cognition/agency. These academics were known for studies on attention, perception, learning and adaptation, memory, happiness, brain development, and anti- and pro-social behaviour. Their disciplinary perspectives were varied, and though most described themselves as cognitive neuroscientists broadly, their backgrounds included experimental psychology, medicine, clinical psychology, computational neuroscience, social neuroscience, and a more integrated ‘social, cognitive and affective neuroscience’. The interviews were conducted by the author and a research assistant.

ⁱⁱⁱ Given the limitations of space, the present article does not consider related issues of epigenetics, which examines genetic responses to environmental conditions, nor epidemiological studies of mental health, nor cognition in terms of learning and development. Instead the focus is on the more basic cognitive *processes*, including attention and perception, as well as non-cognitive neural functions which signify the apparent interface between mind, brain and world.

^{iv} Some of the material presented in this section appears in: author, 2015

^v Other geographical approaches and themes would provide additional insight – for example, extensive geographical research on wellbeing and mental health, developments in emotional geographies, and psychoanalytic geographies. All of these areas make important contributions to rethinking the relationships between space, place, context and the human mind, often providing a useful challenge to existing preoccupations with cognition, rationality and consciousness. For the purposes of this paper I focus on the geographical approaches which have arguably had the most sustained engagements with cognitive and neuroscience research.

^{vi} But note how the notion of ‘critical distance’ has itself been problematized, by Rose and Abi-Rached (2013:8) who are unconvinced by the “overgeneralized critiques of ‘neuromania’ and other fundamentally defensive reactions from the social and human sciences”, and by Callard and Fitzgerald (2015: 44) who want to “do away with the mirrored image of the neuroscientist either as a sort of crude empiricist, waiting patiently for the philosopher to sort out her concepts, or as an external intellectual imperialist, blithely washing sociological histories away with her all-conquering brain machine”.