

From the Neuron to the World and Back: The Poetics of the Neuromolecular Gaze in Bart Koubaa's *Het gebied van Nevski* and James Cameron's *Avatar*¹

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Abstract

This article explores the poetics of the neuromolecular gaze in Bart Koubaa's 2007 novel *Het gebied van Nevski* and James Cameron's 2009 film *Avatar*. It considers the novel and the film as artistic reflections of contemporary neuroculture and argues that they both employ their central metaphors – the brain as battlefield and the brain as network – in such a way that the same basic principles seem to return on various levels of biological and social existence: the micro-level of nerve cells and synapses, the meso-level of individual brains and human beings and the macro-level of historical events and socio-political interaction. In doing so, the novel and the film both suggest a natural continuity between the neurobiological and the social that closely resembles manifestations of the 'neuromolecular gaze' (Rose/Abi-Rached) in contemporary science and neuroculture at large. Significantly, however, these poetic extrapolations of neuromolecular knowledge to personal identity and society do not lead to a homogeneous and reductionist view of the 'cerebral subject' (F. Vidal) but to quite diverse, ambiguous and contradictory interpretations of what it means 'to be one's brain'.

Keywords: Brain, Neuroculture, Darwinism, Network, Metaphor, Cerebral Subject, Poetics of Knowledge, Literature and Science

Humanoid Neurons

One of the key passages of Bart Koubaa's 2007 novel *Het gebied van Nevski* depicts a microscopic battle scene. The theatre of war is situated within the brain of the

narrator of the text, a Flemish writer living in the city of Ghent, and observed via an advanced neuroimaging technique that his doctors use to study a newly discovered area in his cerebrum. Zooming in on this so-called ‘Nevsky’s area’, the neurologists witness a violent battle of nerve cells (neurons) that seem to encode competing thoughts and memories in the writer’s brain. They see how ‘strong’ nerve cells start to swing and cluster together in a ‘very specific rhythm’, thus forming new groups and alliances while other neurons are cast out. When combat is over, the victorious majority of cells makes a ‘treaty’ with the ‘strongest memory’ that is then reported to other areas of the brain. Neurons ‘killed in action’ are buried and ‘collaborators, spies and informants’ immediately executed.² This anthropomorphic description establishes the fictitious ‘Nevsky’s area’ as an important hot spot in the writer’s creative brain and metaphorically links the events in its neural structures to a historical conflict and its film adaptation by Sergei Eisenstein that plays a crucial role in the novel, namely the famous ‘Battle on the Ice’ between the army of Alexander Nevsky, the prince of Novgorod, and the Teutonic Knights on Lake Peipus in 1242 (Fig. 1).

A quite different but yet curiously similar transfiguration of humanoids and nerve cells occurs in another product of contemporary neuroculture, James Cameron’s science fiction film *Avatar* from 2009. In two scenes towards the end of the film we see large groups of Na’vi, the tall and blue-skinned humanoid inhabitants of Pandora, gather around their sacred ‘Tree of Souls’ in an attempt to transfer the minds of two human beings to Na’vi bodies. The participants in the ceremony sit down, connect their long braids to a network of fibres on the ground of the forest and start to move their upper bodies synchronously to the rhythm of a spiritual chant (Fig. 2). When the camera pans out and shows the gathering in its entirety, the network of interconnected Na’vi resembles a giant cerebral cortex.³ The individual Na’vi appear as single nerve cells – humanoid neurons – within a large neural tissue whose nervous and spiritual energy is expected to save the earthlings. Hence, just like Koubaa’s novel, the film stages a figurative conflation of neurons and neuronal groups with human(oid) beings and forms of social interaction.

In this article, I will read *Het gebied van Nevski’s* and *Avatar’s* representational strategies in the context of contemporary ‘neuroculture’, i.e. the interdiscursive fascination with the brain as the source and biological substrate of human conduct and identity. More specifically, I will analyze the novel and the film as artistic modifications of and responses to a scientific style of thought that sociologists of medicine Joelle M. Abi-Rached and Nikolas Rose have termed the ‘neuromolecular gaze’. This style of thought is based on the assumption that any understanding of the workings of the brain and mental processes must start at the ‘molecular’ level of nerve cells and then ‘scale up’⁴ to the higher levels of neural networks, cerebral regions and the brain as a whole. I will argue that by creating systems of analogy that visually and linguistically link the micro-level of

neurons and synapses to the meso-level of individual brains and the macro-level of social interaction, *Avatar* and *Het gebied van Nevski* perform their own versions of the neuromolecular gaze. They thereby employ what I suggest to call a poetics of the neuromolecular gaze, i.e. representational and associative strategies that suggest a natural continuity between the cellular, the cerebral and the social. In this way they participate in what has been called the ‘seductive allure’⁵ that contemporary neuroscience exerts on the popular imagination by suggestive and reductionist forms of reasoning that claim direct relations between social processes, mental states and their alleged ‘neural correlates’. These strategies certainly call for discursive analysis and ideological critique; they do not, however, necessarily lead to a homogenous and hegemonic neuro world-view, as some critics of the present ‘neuro-hype’ fear. *Avatar* and *Het gebied van Nevski* are cases in point: because they use different tropes to ‘scale up’ from the neuronal to the social – the Darwinian trope of the ‘brain as a battlefield’ and the connectionist trope of the ‘brain as a network’ – they also project quite different visions of what a ‘neuromolecular’ view of personal identity and social relations could mean.

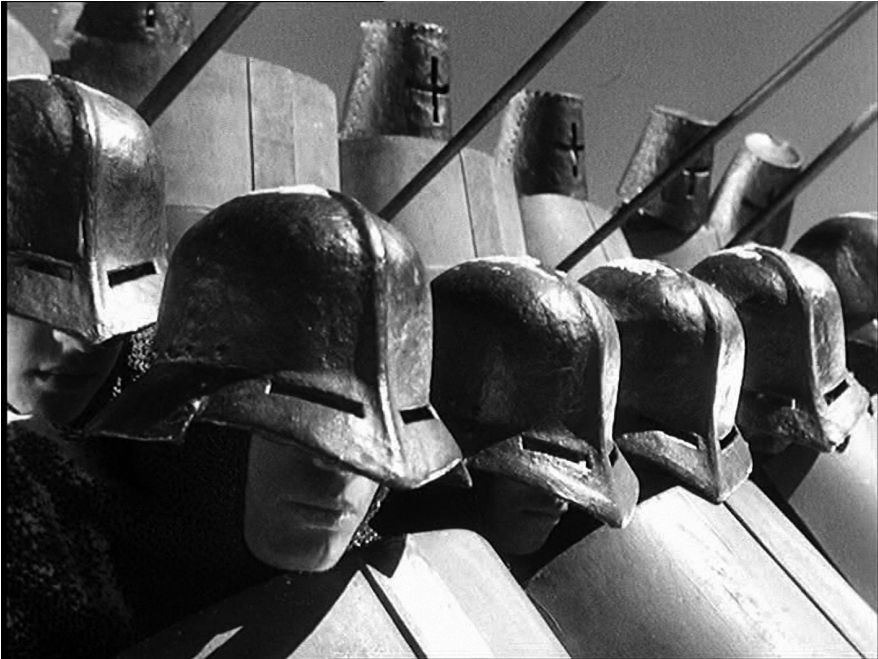


Figure 1 Sergei Eisenstein, *Alexander Nevsky* (1938)



Figure 2 Gathering at the Tree of Souls (James Cameron, Avatar)

The Neuromolecular Gaze and the Cultural Dissemination of the ‘Brain’

The concept of the neuromolecular gaze has been introduced by Joelle M. Abi-Rached and Nikolas Rose in order to describe an epistemological shift that led to the emergence of the modern neurosciences in the 1960s and still is dominant today. Inspired by Michel Foucault’s notion of the clinical gaze and Ludwik Fleck’s concept of the style of thought, the ‘neuromolecular gaze’ comprises, but is not limited to, visual technologies and forms of representation. Like Foucault’s clinical gaze, the neuromolecular gaze is a dissecting and anatomizing gaze, one that literally and figuratively penetrates the body/brain in order to gain knowledge of the processes inside, for instance by the use of neuroimaging techniques. But in Rose and Abi-Rached’s definition the term ‘gaze’ also more broadly refers to a ‘new discourse in the sciences of the brain and the nervous system’⁶ that emerged in the second half of the twentieth century, i.e. a specific research perspective and ‘vision of the brain’⁷ in general. Therefore, I suggest to regard the tropes, metaphors and figures of thought that support this ‘vision’ and facilitate its cultural circulation as an integral part of the neuromolecular gaze as well.

Hence, I propose to combine Rose and Abi-Rached's *epistemological* concept with insights from the current research into the *poetic* dimension of neuroscientific knowledge and its cultural dissemination.⁸ In addition, I will argue that the general disposition to invest the neuromolecular level of nerve cells, neurotransmitters and synapses with specific meaning and relevance when it comes to the explanation and imagination of higher order phenomena such as memory and subjectivity is not limited to scientific discourses. Instead, in this broader definition – the general willingness to relate all kinds of social, cultural and biological phenomena to a neuromolecular 'ground level' – can be seen as an important structuring element of contemporary neuroculture at large.

According to Rose and Abi-Rached, the neuromolecular gaze is both inherently interdisciplinary and 'profoundly reductionist'.⁹ Its interdisciplinarity is the result of a growing awareness of scientists since the 1950s that their efforts in the fields of molecular biology, neuroanatomy, neurology, chemistry, behavioural psychology and other *psy*-disciplines could only lead to a comprehensive understanding of the human mind and brain if they were brought together in a cross-disciplinary research agenda.¹⁰ This also entailed a new conception of the object of research itself: 'The brain was now conceived of as a complex biological system that needed to be dissected and studied from different levels of analysis – cellular, morphological, developmental, behavioral, physiological etc. – and in an integrated manner – what was termed a "synthetic approach".'¹¹ This new integrative approach was institutionalized in research programs and organizations such as the International Brain Research Foundation (established in 1961) and the Neurosciences Research Program at MIT (1962), whose founder Francis O. Schmitt coined the term 'neuroscience' in the same year.¹² The general orientation and rhetoric of this approach can still be found in the self-descriptions of research institutions today. The website of the research priority area 'Brain and Cognition' at the University of Amsterdam, for instance, describes the program's activities as covering 'the entire spectrum from nerve cell to social behavior'.¹³

According to Rose and Abi-Rached, this cross-disciplinary approach is nevertheless reductionist because it privileges the molecular level as the ultimate anchorage point to which all the higher order phenomena of consciousness, cognition and behaviour must be retraced in order to produce valid scientific explanations.¹⁴ Entities such as the human organism and indeed the human 'subject' are seen as 'dissectible, reducible to traits, behaviours, cells, genes, brain processes (like vision or consciousness), to atomic elements: neuromolecular parts that could be "dissected out" and studied separately from the whole.'¹⁵ This means that even fields as psychology, psychiatry and the study of human memory were increasingly dominated by a 'reductionist molecular method',¹⁶ at least until the growing acceptance for the notion of neuroplasticity in the 2000s started to act 'as something of a counterweight to such reductionism'.¹⁷ As an example of the reductionist approach, Abi-Rached and Rose point

to the work of Nobel laureate Eric Kandel on the neurobiology of memory and his maxim that the brain should be studied ‘one cell at a time’.¹⁸ While avoiding any alarmist rhetoric about an alleged ‘colonization’ of society by the neurosciences, Abi-Rached and Rose warn against the ‘premature and unwise extrapolation to society of the modest and always uncertain and correctible knowledge of the laboratory sciences.’¹⁹ In their view, the ‘translational imperative’ under which neuroscientists operate today – i.e. the pressure on and willingness of researchers to quickly translate their laboratory findings into real-world situations – can lead to ‘reckless extrapolations’.²⁰ Animal experiments, for instance, are presented as providing insights into psychiatric disorders in humans,²¹ plasticity research is invoked as neurological legitimation of a neoliberal economic order²² and neurochemical findings are translated into pharmacological ‘solutions’ to psychological problems.

While pointing to these dangers, Rose and Abi-Rached nevertheless take a nuanced position in the current debate about the social and political consequences of the neuro-boom. Not surprisingly, the ‘tentacular growth’²³ of the neurocultural universe has spawned various forms of criticism. As philosopher Jan Slaby pointed out, it is probably harder these days to give examples of cultural, social and academic fields that are not affected by the so-called ‘neuro revolution’²⁴ than to name fields in which claims about the relevance or even revolutionary impact of neuroscientific findings abound; newly emerging disciplines such as neuromarketing or neurophilosophy are cases in point.²⁵ Slaby and others have therefore called for the critical contextualization and analysis of the truth claims of contemporary neuroscience and their ideological implications.²⁶ In a related vein, psychologists Paolo Legrenzi and Carlo Umiltà have attacked the biologism of contemporary ‘neuromania’ and its reductionist approach to the mind-brain relationship.²⁷ In the Netherlands, the enormous success of popular neuroscience books such as Dick Swaab’s bestselling *Wij zijn ons brein* and Victor Lamme’s *De vrije wil bestaat niet* has been countered by psychologist Jan Derksen’s appeal to ‘free psychology’²⁸ from the imperialist encroachment of the ‘brain myth’ and Douwe Draaisma’s rejection of Swaab’s hubristic transgression of disciplinary boundaries.²⁹ Historian of science Fernando Vidal, one of the most outspoken critics of a cultural hegemony of the ‘neuro’, has likewise criticized the neurosciences’ tendency to ‘boast their power to radically alter the view of the human’.³⁰ According to Vidal, contemporary neurocultural discourses propagate a notion of the self that is dominated by the ‘ideology of brainhood’, i.e. the idee of ‘being, rather than simply having, a brain’ and thus the reducibility of the self to one organ. Vidal terms this conception of selfhood the ‘cerebral subject’ and argues that it emphasizes interiority, autonomous choice and individualism ‘at the expense of social bonds and contexts.’³¹ Similar and more specific criticisms of the cerebralization of personhood have been voiced with regard to the ontological impact of neuropsychiatric disease entities and classifications on

the patients' sense of self,³² the links of 'neurochemical' conceptions of personhood with contemporary biopolitics and the interests of the pharmaceutical industry,³³ the mobilization of the 'plastic' brain in neoliberal discourses of flexibility, employability and self-management³⁴ and the neurosexist essentialization of gender identities.³⁵

Although Rose and Abi-Rached share some of these concerns, they do not believe that personhood has or will simply become brainhood. In their view, the cerebral subject is just one of many forms of self-fashioning that are presently employed and mixed in different contexts and departments of life.³⁶ Moreover, they contend that neurobiological conceptions of personhood *themselves* are more diverse than the critics seem to acknowledge and 'do not portray humans as mere puppets of their brains' or "'neuronal man" as isolated, individualized and asocial'.³⁷ Picking up on this argument, I will argue that *Avatar* and *Het gebied van Nevski* precisely point to this inherent diversity of a 'neuro world view' and even amplify it by their use of 'seductive' analogies. On the one hand, the film and the novel show that the neuromolecular gaze is not merely a scientific style of thought but – in its broader definition as a disposition to relate the molecular to the human and the social – forms an important element of contemporary neuroculture at large. On the other hand, the specific calibrations of the neuromolecular gaze in *Avatar* and *Het gebied van Nevski* produce quite different notions of what it means to 'be one's brain'. Hence, by devising their own 'integrated multilevel approaches'³⁸ to the brain and human existence, the novel and the film illuminate the frictions and ambiguities within this gaze as well.

Het gebied van Nevski: The Brain as Battlefield

Bart Koubaa's *Het gebied van Nevski* tells the story of an arduous recovery after a severe case of brain damage. The novel begins with the description of a near-fatal accident during a visit that the narrator, an anonymous Flemish writer, pays to Lake Peipus, the site of the historical battle between Alexander Nevsky and his army against the Teutonic Knights in 1242. A fervid admirer of the historical Nevsky as well as Sergei Eisenstein's 1938 drama film *Alexander Nevskiy*, the writer adventurously strolls around the frozen surface of the lake. He sinks through the ice and sustains a specific form of expressive aphasia that manifests itself in difficulties to produce grammatically correct and coherent sentences. His neurologist professor Van Nieuwenhuyze advises the narrator to keep a diary to order his thinking and rehearse his linguistic skills. This diary or 'brain research',³⁹ as the narrator terms it, is basically identical to the text of the novel itself and is characterized by a highly associative and 'aphasic' style of writing full of neologisms, wordplay and logical short circuits. As the narrator himself puts it: 'I write fluently, but the sentences are not always meaningful for someone with a healthy brain.'⁴⁰

Within the expanding network of contemporary Dutch neuroculture Koubaa's novel forms a particularly thick knot of intertextual references. They include numerous allusions to the history of brain research and neurological localization theories⁴¹ as well as references to more recent developments such as discussions about mirror neurons and the notion of the 'empathic brain',⁴² new neuroimaging techniques, studies of brain plasticity in songbirds⁴³ and philosopher Daniel Dennett's metaphor of the 'Cartesian theater'.⁴⁴ By orchestrating and narrativizing these references, the novel explores the implications of a neuromaterialistic notion of identity. It seems to arrive at a 'conclusion' that pre-formulates the catch-phrase in the title of Dick Swaab's bestseller when the writer opens one of his last entries with the remark: 'Ik ben mijn hersenen.'⁴⁵ This insight and its consequences, however, are not presented as an ultimate truth of the cerebral subject. Instead, the novel constantly oscillates between a serious, knowledgeable engagement with neuroscientific theories and the parodic exaggeration and playful subversion of their philosophical implications.

The most important intertextual reference in *Het gebied van Nevski* in this regard concerns a neuroscientific theory that is known as 'neural Darwinism' or 'theory of neuronal group selection'. One of its best-known representatives, American neurophysiologist William H. Calvin, is repeatedly quoted in the novel with the notion that the brain encodes memories in 'spatial patterns' of nerve cells that are 'frozen in time, a sheet of music waiting for a pianist'.⁴⁶ This conception forms an important element of Calvin's theory of 'Darwinian thought',⁴⁷ according to which the natural selection of neuronal groups in the brain represents the biological substrate of processes of remembering and forgetting. This hypothesis in turn is heavily and explicitly indebted to the theory of 'neural Darwinism' that biologist and Nobel laureate Gerard Edelman proposed in his 1987 study *Neural Darwinism: The Theory of Neuronal Group Selection*. In this book and its popular scientific counterpart *Bright Air, Brilliant Fire* (1992), Edelman controversially applies the principles of Darwinist population thinking to the workings of the brain. He argues that we can only truly understand memory and cognition if we conceive of the brain not as a static storage device or computer but as 'dynamically organized into cellular populations [...] the structure and function of which are selected by different means during development and behavior'.⁴⁸ According to Edelman, these groups of strongly connected neurons constantly compete for electrochemical stimulation. This competition results in a selective strengthening and weakening of synaptic connections and neuronal groups through processes of cell division and cell death during growth and development of an organism (*developmental selection*), through behaviour and learning during an individual's life (*experiential selection*) and the massively parallel second-order signaling between neuronal groups (*reentry*).⁴⁹

It is this particular piece of neuromolecular knowledge that serves to anchor and orient the neuromolecular gaze in *Het gebied van Nevski*. It provides material

evidence for the novel's central trope of the 'brain as battlefield' which in turn forms the framework for the playful superimposition of various layers of Darwinist imagery, ranging from the submicroscopic realm of cells and synapses over the medium level of individual brains up to the macro-scale of historical events and social interaction.

On the cellular level, Koubaa employs the trope of the 'battle' by comparing individual neurons with 'tiny soldiers' in the writer's head and stating that 'on average one hundred thousand [of them] fall in battle daily.'⁵⁰ This analogy of cells and soldiers recalls alchemist theories of the homunculus and recasts them in a neural Darwinist fashion. In accordance with the theory of neuronal group selection, the formation of thoughts and memories in the writer's brain is described as an 'evolutionary process' and struggle for life in which dreams, memories and ideas 'pitch into each other like samurais'.⁵¹ This evolutionary principle also seems to be at work when professor Van Nieuwenhuyze struggles to recall the title of Eisenstein's *Alexander Nevsky* because the thought of another historical Alexander – Alexander the Great – 'overgrows and suffocates'⁵² the sought-after piece of information in his brain.

Since the narrator believes that he literally is his brain, the notion of the 'battle' also directly concerns his conception of identity and sense of self. To him, this self appears as an ever changing 'pattern' of thoughts and memories and thus synaptic connections that constantly compete, copy and transform themselves.⁵³ In addition, the notion of battle is also applied to the text of the diary itself – 'everything you read has fought in my brain for the space on these pages'⁵⁴ – and to literary works in general that appear as the result of a 'Darwinian evolutionary process'⁵⁵ of adaptation to specific cultural environments and product of sexual selection: 'Language is the tail that the writer shows off'.⁵⁶ Importantly, this metonymic shift from biological matter – nerve cells and neuronal groups – to text and literature is facilitated by another trope that carries strong associations with evolutionary theory, namely the metaphor of the four 'letters' of the 'alphabet' of the genetic code.⁵⁷ Once again musing about the bio-ontological status of his own writing, the narrator reasons: 'If I indeed am nothing else than the four letters A, C, G, and T, the combination of which makes up the machine language of my construction, then it must be possible to construct all my memories [...] from them as well; then my fingers [on the computer keyboard, SB] must be able to play the song of our existence.'⁵⁸

Finally, Koubaa also deploys the trope of the battle on the supra-individual level of historical events and human sociality. As mentioned before, the emphasis here lies on the world-historical battle between the Teutonic Knights and Alexander Nevsky's motley army 'of peasants, fishermen and crafts people'⁵⁹ (who in turn are likened to the words on the pages of his diary with which the narrator fights his aphasia). In addition, there is a sustained comparison of the street map of the city of Ghent with the topography of the human brain in which the search

for the stolen panel ‘The Just Judges’ of the famous Ghent altarpiece by Jan and Hubert Van Eyck merges with the scientific quest for the location of morality in the human brain.⁶⁰ The social Darwinist and racist implications of the novel’s central trope also briefly come to the fore when the narrator ruminates that the nationalistic motto ‘*Eigen Volk Eerst*’ (Put your own people first) is not actually a ‘political slogan’ but the expression of an age-old human characteristic in dealing with strangers.⁶¹

It is essential to point out that in the text of the novel itself the various instantiations of the battle trope are not as neatly separated as my rather schematic synopsis suggests; instead, they constantly overlap, intersect and resonate with each other. Still, the cellular or ‘neuromolecular’ level provides the most important point of reference for this complex arrangement of analogies that resembles a dizzying hall of mirrors in which ‘battles’ of various kinds and on various levels of existence reflect, deform and thwart each other. Abounding with logical fallacies, false syllogisms and fantastic associations, the text employs and exposes the reductionism inherent in the notion that all these battles express the ‘same’ basic biological principle.

It is precisely because of this double movement that the poetics of the neuromolecular gaze in Koubaa’s novel can shed an interesting light on popular and neuroscientific attempts to integrate the various levels of biological and social existence into a coherent Darwinist view of human existence.⁶² In contemporary neuroscience itself, for instance, it is still hotly debated whether Edelman’s ‘neuronal groups’ can actually be regarded as clearly definable units of selection that are able to replicate themselves, as a properly ‘Darwinian’ process of evolution would imply. Because of such open questions, molecular biologist and Nobel Prize laureate Francis Crick has famously suggested that Edelman’s idiosyncratic interpretation of evolutionary theory should be called ‘neural Edelmanism’ instead of ‘neural Darwinism’.⁶³ (Interestingly, Edelman himself has occasionally described ‘neural Darwinism’ as a ‘metaphor’,⁶⁴ suggesting that these processes are similar rather than the same.)

This discussion also directly relates to another problem of neural Darwinism that is addressed in Koubaa’s novel, namely the relation of genes and nerve cells in theories of the brain. Significantly, Edelman himself opposes any genetic determinism and rejects the notion that the circuitry of neuronal groups could be ‘strictly programmed by a molecular code’.⁶⁵ Instead, Edelman’s focus on the cellular level implies an emphasis on *epigenetic* processes of selection and reentrant signaling, resulting in a dynamic conception of neural connectivity that is in many regards akin to more recent theories of neuroplasticity. Therefore, his view of the brain and human subjectivity is remarkably different from other, equally ‘Darwinist’ approaches that instead focus on the genetic basis of the wiring of neural networks.

An interesting case in point is Dick Swaab's aforementioned popular neuroscience bestseller *Wij zijn ons brein*. On the one hand, Swaab's book is decidedly and even provocatively Darwinist in many regards: Several of the chapters are preceded by mottos taken from the writings of Charles Darwin himself, there is a substantial chapter on the evolutionary history of the human brain in which Swaab explains the genetic determination of human behaviour and cultural practices⁶⁶ and a consistent emphasis on the importance of genetics and the prenatal wiring of the brain in the uterus: 'We are born with brains that have been made unique by a combination of our genetic background and the programming during our development in the womb. These influences determine to a significant extent our personal character traits, talents and limitations.'⁶⁷ Correspondingly, Swaab depicts the influence of social and cultural environments on an individual's brain after birth as almost negligible; the only changes in adult brains that he discusses concern degenerative disorders such as Alzheimer's and Parkinson's disease.

Importantly, it is exactly this inclination towards genetic determinism that makes Swaab's book not an example of neural Darwinism, even though its author occasionally – and not quite convincingly – refers to Edelman's notion in support of his own approach.⁶⁸ While Swaab sees brain plasticity as limited to the early developmental stages, Edelman insists that the competition and selection of neural groups do not stop in adults and regards the cellular dynamics of neural maps as a 'continuing process throughout the life of an individual organism'.⁶⁹ For the same reason Edelman unambiguously rejects all computer metaphors of the brain because they suggest a 'hardwired' nervous system whereas Swaab explicitly embraces them.⁷⁰

In contemporary neuroculture this distinction between gene-centred and neuron-centred approaches translates into rather different conceptions of neuro-identity: deterministic and 'neurocalvinist' views such as the one popularized by Swaab on the one hand and flexible and plastic conceptions of the 'synaptic self'⁷¹ on the other. By combining both options in a way that resembles the confusing poly-perspectivism of a cubist painting, Koubaa's novel points to the diversity of possible 'extrapolations' (Abi-Rached and Rose) of neuromolecular knowledge in present day neuroculture.

***Avatar*: The brain as network**

This picture becomes even more complex if one takes into consideration that the metaphor of the battle is just one of many possibilities to construct a meaningful continuity between neurons, humans and society at large. In James Cameron's *Avatar* this function is fulfilled by a trope that is at least equally important in contemporary neuroculture, namely the notion of the 'network'. Accordingly, the calibration of the neuroscientific gaze in Cameron's film significantly di-

verges from Koubaa's novel and produces quite different meaning effects, inter-discursive links and extrapolations of neuroscientific knowledge to human subjectivity. In addition, the specific cinematic mediality of the film, enhanced by stereoscopic 3D technology, facilitates the construction of visual analogies in a way that cannot be achieved in literary texts.

Avatar is set in the mid-twenty-second century on Pandora, a habitable moon of the gas giant Polyphemus in the Alpha Centauri star system. After the depletion of Earth's natural resources, the Resources Development Agency (RDA) mines on Pandora for a valuable mineral called unobtainium. The film tells the story of the increasingly violent conflict between the Na'vi, the native inhabitants of Pandora, and the armed forces that protect the mining activities of the RDA. It is the task of a research team lead by xenobotanist Dr Grace Augustine to further explore Pandora's biosphere and persuade the Na'vi to leave their territory so that even larger areas of Pandora can be exploited by the RDA. Augustine and her staff, however, become increasingly critical of the destruction of the settlement areas of the Na'vi and their culture and eventually join their resistance against the RDA 'security forces'. After an epic battle in which Eywa, the mother goddess of the Na'vi, intervenes by sending giant dinosaur-like creatures to the rescue of her children, the balance of life is restored and the earthlings are expelled from Pandora.

Significantly, the escalation of this increasingly violent conflict is contrasted with an entirely different 'escalation' – in the literal sense of an increase and development of successive stages – of the network trope in the film, starting on the neurocellular level and leading to the eventual revelation halfway through the film that the biosphere of Pandora in its entirety is a actually giant super-brain. This second escalation begins with what can be regarded as the establishing shots of the neuromolecular gaze in *Avatar* during an extensive laboratory scene at the beginning of the film. We see how the paraplegic ex-marine Jake Sully, a new member of Dr Augustine's research team, is prepared for the first connection with his avatar, a genetically engineered and neurologically operated replica of the body of a Na'vi. The visual aesthetics of this scene are dominated by high-tech laboratory equipment, transparent computer screens and the imagery of brain scans flashing up in green, yellow and white. While the scientists attempt to synchronize Jake's neural activity with that of the avatar – 'Their nervous systems must be in tune' – one of the neuroimaging devices zooms in on the neural pathways and the microstructure of the synaptic connections in Sully's brain (Fig. 3). When Jake's mind is actually connected to its new host, the camera eye itself seems to be transported through a tunnel-like neural pathway into the avatar's head.⁷²

With its neuronal imagery thus firmly anchored on the cellular level, the film successively adds new layers and dimensions of network images that, as film scholar Patricia Pisters has pointed out, 'at every level reproduce our neural



Figure 3 Scanning the brain, seeing networks (James Cameron, *Avatar*)

system’ and ‘stretch out in all directions like an overflowing brain’ themselves.⁷³ The most conspicuous instantiation of the network trope at the meso-level of humanoid and animal organisms is a psychobiological linking procedure called ‘the bond’ (*tsaheylu*). This bond is established when the Na’vi connect their long queues – hair-like extensions of their nervous systems – to other organisms such as the horse-like or dragon-shaped creatures of Pandora they use as means of transport. The form and look of the queues are clearly modelled on visual representations of nerve cells, with the braid resembling the elongated cell body (*soma*) and the fringy endings bearing a close likeness to dendrites, the branched projections of nerve cells named after the Greek term for ‘tree’ (*dendron*).

On an even more comprehensive bio-spiritual level, the entire biosphere of Pandora, dominated by lush and dense jungles, gradually turns out to form a giant nervous network. On this level, it is mainly the entanglement of lianas and branches, air roots, trees and climbing plants that visually produces the similarity to actual neural networks as first presented in the laboratory scene. The film here reiterates a long tradition of comparing nerve cells to trees and forests that goes back at least to the Spanish neuroscientist Ramón y Cajal (1852-1934), a pioneer of the cellular approach in neuroanatomy. Ramón y Cajal famously spoke of the cellular ‘forest’ of the brain and compared the cerebrum to a ‘tree whose foliage spreads out’⁷⁴ in order to emphasize the ability of brain cells ‘to respond to the environment by growing in new directions’.⁷⁵ This aspect also comes to the fore in Gerard Edelman’s frequent use of botanical imagery, for instance when he talks about branches of axons as ‘arbors’,⁷⁶ ‘dendritic trees’⁷⁷ or the ‘aborization’⁷⁸ of nerve fibres.



Figure 4 The floating mountains of Pandora (James Cameron, *Avatar*)

In *Avatar*, however, this linguistic and visual analogy is not only repeated but pushed to a new level by the effective employment of 3D filming technology. This technique visually enhances the representation of the Pandora jungle as a three-dimensional space that resembles the spatiality of an actual brain as a three-dimensional object: the kind of object the viewers have seen in the holographic projections of brains and neural pathways at the beginning of the film. The potential of these new cinematic possibilities is fully and spectacularly played out when Augustine's research team explores the 'legendary floating mountains' of Pandora by helicopter. Consisting of huge rocks and lumps of earth suspended in mid-air and connected by lianas and other plants, these 'floating mountains' visually resemble clusters of neurons (ganglions) and give a new dimension to the spatial experience of Pandora as a giant brain (Fig. 4).⁷⁹ The spectacular flight scenes and nose dives of the camera eye in *Avatar* therefore are more than just effective means of an action film to create thrill and excitement, they have an epistemological dimension as well: they visually superimpose neuronal and planetary spaces and thus contribute to the film's attempt to show the microscopic in the global and the giant in the small.

After this extensive audiovisual elaboration of the network trope it hardly comes as a surprise when Grace Augustine eventually introduces this notion on a linguistic level as well. In a heated conversation with Parker Selfridge, the head administrator of the RDA on Pandora, she explains:

What we think we know is that there is some kind of electrochemical communication between the roots of the trees, like the synapses between neurons. And each tree has ten-to-the-fourth-connections to the trees around it. And there are ten-to-the-twelfth trees on Pandora. [...] It's more connections than the human brain. Get it? It's a network. It's a global network and the Na'vi can access it. They can upload and download data. Memories.⁸⁰

Eventually, this network proves to be a global autopoietic system, (dis-)embodied in the 'great Mother' Eywa, that is able to regain homeostasis after disturbance from outside, in Gaia style. An appropriately postcolonial reading of the film could conclude that it is not so much the 'empire' but the system/network that strikes back when Eywa sends her help after Jake Sully's distress call via the fibre optical branches of the Tree of Souls.

Despite the film's holistic approach, however, the use of the network as a *passé-partout* analogy for all forms and levels of life is in no less problematic than the universal neuro-Darwinism exposed in Koubaa's novel. In an enthusiastic review of Cameron's film, American biologist and science writer Carol Yoon praised *Avatar* for artistically recreating 'what is the heart of biology: the naked, heart-stopping wonder of really seeing the living world'.⁸¹ One should add that the film combines this fascination with the 'living world' with constant references to contemporary discourses of the 'global brain' and the internet as an emerging 'central nervous system for humanity'.⁸² By suggesting a natural continuity between biological and technological networks, *Avatar* glosses over important differences between them. In this regard, the film's use of the network analogy recalls the attempts of the connectionist movement in cognitive science to project the properties of neuronal tissues on artificial neural networks and vice versa. As Douwe Draaisma has shown, these cross-mappings made researchers overlook the fact that the parallels were actually 'minimal or superficial': unlike the individual units of neural networks, actual neurons exhibit great mutual differences in construction and function; moreover, their activity is 'modulated by chemical processes under hormonal control'.⁸³ More recently, Nicholas Carr has pointed out that representations of the internet as a global nervous network are fundamentally mistaken because they fail to see the profound differences between hyperlinks and the 'organic richness and sensitivity'⁸⁴ of synapses. By employing a universal 'networkism', *Avatar* participates in the current naturalization of new communication technologies and contributes to depictions of the 'network society' and 'network economy' as *natural* outcomes of processes of globalization. Along this line of criticism, media scholar Ken Hillis has convincingly pointed to the 'fetishization of new digital technologies' and the ideological conflation of biology, spirituality and technology in the film: '*Avatar*'s core politics are animated by its depiction of an idealized future society predicated on a carbon-based, biological network of networks operationalized through the meta-

physical logic of World Soul.⁸⁵ As an example, one could cite the film's seamless integration of the flashy laboratory aesthetics of brain scans and holographic projections with the glossy and beaming representation of the Pandorian jungle and its fibre optical elements. This visual, narrative and epistemic integration of nature, neurons and society in *Avatar* is the result of a specific calibration of the neuromolecular gaze on the basis of *analogy*: a comparison that highlights and constructs similarities but also obscures and blocks out fundamental differences between source and target domain.⁸⁶

Yet, although the poetics of the neuromolecular gaze in *Avatar* are far less critical and self-reflexive than in Koubaa's novel, the film does not simply subscribe to a reductionist notion of the cerebral subject. Instead, it seems to privilege a conception of identity that is informed by the so-called '4AE approach' in contemporary neuroscience and philosophy. This acronym refers to a wide range of approaches that study the mind as an embodied, embedded, enacted, extended and affective phenomenon.⁸⁷ They include Andy Clark's concepts of the extended mind and the dynamic loops between world and brain as well as Francisco Varela, Evan Thompson and Eleanor Rosch's anti-dualist theory of embodied and 'enactive' cognition and, by extension, Bruno Latour's Actor-Network Theory.⁸⁸ Combining allusions to several of these approaches, *Avatar* can be read as an imagination of 'situated subjectivity'⁸⁹ that is in touch with what Rose and Abi-Rached describe as theories of the 'social brain' that 'locate neural processes firmly in the dimension of time, development, and transactions with a milieu'.⁹⁰ In the narrative and visual language of the film this environmental approach to subjectivity also implies a turning away from genetics that, on a symbolic level, goes much further than for instance Gerald Edelman's. After the destruction of their 'Hometree', a giant arboreal structure that through the spiral structure at its core is closely associated with genetics, the Na'vi move on to the fibre optical Tree of Souls and, literally, to a networked and epigenetic existence.

Conclusion

I have argued that *Avatar* en *Het gebied van Nevski* can be read as examples of what I suggest to call the poetics of the neuromolecular gaze: the projection of neuromolecular imagery onto other levels of biological and social existence by means of analogy. The film and the novel implement these poetics in quite different ways: They employ different tropes – the brain as battlefield and the brain as network – as basis for the projection of analogies and use different representational techniques and strategies for creating them (verbal and visual association, neologisms, wordplay, editing, lighting, etc.). In doing that, both the film and the novel also deviate from a unidirectional bottom-up approach that regards the molecular level as an ultimate site of truth and knowledge. *Het gebied van Nevski*, for instance, constantly shuffles back and forth between different levels of exis-

tence, resulting rather in a profound epistemological disorientation than in the affirmation of a solid molecular ‘ground level’ of being. Nevertheless, the novel assigns a certain poetic privilege to this level by using it as its most important reservoir of imagery. *Avatar* in turn can be seen to at least point to a mutual unfolding of microscopic and cosmic perspectives that renders any epistemic or poetic privilege of molecular processes questionable.⁹¹ At the same time, the steady narrative unfolding of the network trope from the micro-level of synapses and neural pathways to the networked global brain of Pandora orders these perspectives in a specific way and suggests a particular relevance of the molecular dimension as a general point of reference for everything that is to follow in the film’s tale of conflict and equilibration.

It would take further research to determine the scope of the neuromolecular gaze in contemporary culture and to investigate the influence of popular imageries and artistic representations of the brain on neuroscience itself.⁹² Here, I would like to conclude that precisely *because* the film and the novel give in to the neurocultural ‘lure of translations’⁹³ in different ways they also show that the fascination with the neuronal matter of the brain does not necessarily lead to a reductionist world-view or conception of the cerebral subject. Whereas Fernando Vidal, Francisco Ortega and other critics of contemporary neuroculture tend to identify the cerebral subject with a more or less stable and univocal ideology of ‘brainhood’, the novel and the film point to quite diverse answers to the question what it means ‘to be one’s brain’. *Avatar* even manages to combine a neuromolecular perspective with a vision of situated and embodied subjectivity that neurocritics Jan Slaby and Suparna Choudhury credit for standing ‘in sharp contrast’⁹⁴ to the notion of the cerebral subject. It seems that the ‘seductive allure’ of contemporary neuroscience not only resides in the simplicity and the reductionism of the explanations it offers but also in their ambiguity, diversity and poetic potential. In the process of its cultural dissemination, the neuromolecular imagination itself is ‘lured’ into different directions by the various tropes, metaphors and analogies that it employs in order to gain cultural relevance and to move from the lab into the world.

Notes

1. I would like to thank the members of the research group ‘Neuroaesthetics and Neurocultures’ at the University of Amsterdam for their challenging, insightful and inspiring comments on an earlier version of this text.
2. ‘In het gebied kunnen we niet alleen herinneringen zien concurreren, en ik zeg wel degelijk “zien” omdat het professor Duchamps eindelijk gelukt is om deze in beeld om te zetten, maar ook, en dat is verbluffend, kunnen we in datzelfde gebied vaststellen hoe op een heel specifiek ritme combinaties ontstaan van sterke elkaar aantrekkende cellen en hoe andere worden verstoten. We nemen aan dat die zich vormende meerderheid van cellen een verdrag sluit met de sterkste herinnering om dat daarna

- bekend te maken. [...] De cellen die geen deel uitmaken van dit verdrag, ruimen het puin en begraven de gesneuvelden waarna ze verslag uitbrengen in andere gebieden. Collaborateurs, spionnen en informanten worden onverbiddelijk geëxecuteerd.' B. Koubaa, *Het gebied van Neuski* (Amsterdam: Querido, 2007), p. 85. All translations are mine unless indicated otherwise.
3. *Avatar* (James Cameron, USA/UK, 2009), 01:54:00-01:56:00 and 02:27:30-02:28:45.
 4. N. Rose and J. M. Abi-Rached, *Neuro: The New Brain Sciences and the Management of the Mind* (Princeton and Oxford: Princeton University Press, 2013), p. 229. Rose and Abi-Rached roughly identify the 'neuromolecular level' with the 'communication along and between neurons' (p. 43).
 5. J. Slaby, 'Steps towards a Critical Neuroscience', in *Phenomenology and the Cognitive Sciences* 9 (2010), 397; C. Fine, *Delusions of Gender: How Our Minds, Society, and Neurosexism Create Difference* (New York: W.W. Norton & Company, 2010), p. 171.
 6. J.M. Abi-Rached and N. Rose, 'The Birth of the Neuromolecular Gaze', in *History of the Human Sciences* 23 (2010), 11-36 (p. 12, p. 17).
 7. Rose and Abi-Rached, *Neuro*, p. 38.
 8. See for instance D. Draaisma, *Metaphors of Memory: A History of Ideas about the Mind*, trans. by Paul Vincent (Cambridge: Cambridge University Press, 2000); C. Borck, 'Toys are Us: Models and Metaphors in Brain Research', in *Critical Neuroscience: A Handbook of the Social Cultural Contexts of Neuroscience*, ed. by S. Choudhury and J. Slaby (Chichester: Wiley-Blackwell, 2012), pp. 113-34.
 9. Rose and Abi-Rached, *Neuro*, p. 10.
 10. Rose and Abi-Rached, *Neuro*, pp. 25-8, pp. 41-7.
 11. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 24).
 12. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 20).
 13. 'Zo dekt het onderzoek het volledige spectrum van hersencel tot sociaal gedrag af.' *Brain and Cognition: Zwaartepunt*. <http://www.uva.nl/onderzoek/onderzoek-aan-de-uva/zwaartepunten/content/brain-and-cognition/brain-and-cognition.html> [last accessed April 10, 2013].
 14. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p.11, p. 13). Also see Rose and Abi-Rached, *Neuro*, pp. 9-11, pp. 41-51.
 15. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 24).
 16. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 11). Also see Rose and Abi-Rached, *Neuro*, pp. 11-2.
 17. Rose and Abi-Rached, *Neuro*, p. 51. For a basic definition of the concept Abi-Rached and Rose cite the Wikipedia entry on "Neuroplasticity" (December 2010) that describes the phenomenon as 'the ability of the human brain to change as a result of one's experience' (*Neuro*, p. 48).
 18. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 24); Rose and Abi-Rached, *Neuro*, p. 45. See E. Kandel, *In Search of Memory: The Emergence of a New Science of Mind* (New York / London: W.W. Norton & Company, 2007), p. 55.
 19. Abi-Rached and Rose, 'The Birth of the Neuromolecular Gaze', 11-36 (p. 32).
 20. Rose and Abi-Rached, *Neuro*, p. 228.
 21. Cf. Rose and Abi-Rached, *Neuro*, pp. 82-109.

22. Cf. C. Malabou, *What Should We Do With Our Brain?*, trans. by Sebastian Rand (New York: Fordham University Press, 2008), pp. 40-46 and V. Pitts-Taylor, 'The Plastic Brain: Neoliberalism and the Neuronal Self', *Health* 14.6 (2010), 635-52.
23. F. Vidal and F. Ortega, 'Approaching the Neurocultural Spectrum: An Introduction', in *Neurocultures: Glimpses into an Expanding Universe*, ed. by F. Ortega and F. Vidal (New York: Peter Lang, 2011), p. 18.
24. Z. Lynch with B. Laursen, *The Neuro Revolution: How Brain Science is Changing our World* (New York: St. Martin's Press, 2009).
25. J. Slaby, 'Perspektiven einer kritischen Philosophie der Neurowissenschaften', *Deutsche Zeitschrift für Philosophie* 59.3 (2011), 375-390 (p. 375).
26. See the essays collected in S. Choudhury and J. Slaby (eds), *Critical Neuroscience: A Handbook of the Social and Cultural Contexts of Neuroscience* (Chichester/Oxford: Wiley-Blackwell, 2012).
27. P. Legrenzi and C. Umiltà, *Neuromania: On the Limits of Brain Science* (Oxford: Oxford University Press, 2011).
28. J. Derksen, *Bevrijd de psychologie uit de greep van de hersenmythe* (Amsterdam: Bert Bakker, 2012).
29. D. Draaisma, "'It's all right, I'm a doctor.'" Grensoverschrijding in de wetenschap', in *De Academische Boekengids* 88 (September 2011), 10-2.
30. Vidal and Ortega, 'Approaching the Neurocultural Spectrum', p. 8.
31. F. Vidal, 'Brainhood, Anthropological Figure of Modernity', in *History of the Human Sciences* 22.1 (2009), 5-36 (p. 5, p. 6, p. 7). See also Vidal and Ortega, 'Approaching the Neurocultural Spectrum', pp. 15-9; S. Choudhury and J. Slaby, 'Introduction: Critical Neuroscience – Between Lifeworld and Laboratory', in *Critical Neuroscience*, ed. by Choudhury and Slaby, pp. 7-12.
32. See for example J. Slaby 'Steps towards a Critical Neuroscience', 397-416 (pp. 400-16); S. Cohn, 'Disrupting Images: Neuroscientific Representations in the Lives of Psychiatric Patients', in *Critical Neuroscience*, ed. by Choudhury and Slaby (2012), pp. 179-94.
33. N. Rose, 'Neurochemical Selves', *Society* 41.1 (2003), 46-59.
34. Pitts-Taylor, 'The Plastic Brain: Neoliberalism and the Neuronal Self', pp. 639-46.
35. Fine, *Delusions of Gender*.
36. Rose and Abi-Rached, *Neuro*, pp. 219-22. Vidal and Ortega likewise acknowledge that the cerebral subject should not be regarded as a 'monolithic and hegemonic' notion of personhood, since in actual human experience and identity formation it constantly interacts with other notions of the self. They nevertheless present 'brainhood' itself as a more or less stable category ('Approaching the Neurocultural Spectrum', pp. 17-8).
37. Rose and Abi-Rached, *Neuro*, p. 226.
38. Abi-Rached and Rose, 'Birth of the Neuromolecular Gaze', 11-36 (p. 13).
39. Koubaa, *Het gebied van Nevski*, p. 18.
40. 'Ik [...] schrijf vloeiend, maar de zinnen hebben niet altijd betekenis voor iemand met gezonde hersenen.' Koubaa, *Het gebied van Nevski*, p. 15.
41. Of particular importance in this regard is Jan Verplaetse's study *Het morele brein. Een geschiedenis over de plaats van de moraal in onze hersenen* (Antwerpen: Garant, 2007) that forms the blueprint for a subplot of the novel.
42. Koubaa, *Het gebied van Nevski*, p. 88.

43. Koubaa, *Het gebied van Nevski*, p. 80.
44. Koubaa, *Het gebied van Nevski*, p. 78; see D. Dennett, *Consciousness Explained* (London: Penguin, 1993), pp. 113-5, pp. 137-44.
45. 'I am my brain.' Koubaa, *Het gebied van Nevski*, p. 123.
46. W. Calvin, 'How to Think What No One Has ever Thought before', in *How Things Are: A Science Tool-Kit for the Mind*, ed. by J. Brockman and K. Matson (New York: William Morrow, 1995), p. 161. Explicit references to Calvin and the content of this chapter in Koubaa, *Het gebied van Nevski*, p. 24 ('[...] dat "herinneringen in de tijd bevroren ruimtelijke patronen zijn, een vel bladmuziek dat op een pianist ligt te wachten"') and p. 126.
47. Calvin, 'How to Think', p. 159.
48. G. Edelman, *Neural Darwinism: The Theory of Neuronal Group Selection* (New York: Basic Books, 1987), pp. 4-5.
49. Edelman, *Neural Darwinism*, pp. 4-8. Also see G. Edelman, *Bright Air, Brilliant Fire: On the Matter of the Mind* (London: Penguin, 1994), pp. 80-98.
50. 'Ik sluit mijn ogen en ontwaar een wirwar van dansende kleuren waartussen minuscule soldaten oplichten'; 'Dagelijks sneuvelen er gemiddeld honderdduizend.' Koubaa, *Het gebied van Nevski*, p. 124, p. 123.
51. Koubaa, *Het gebied van Nevski*, p. 44, 72; also see p. 54 and p. 114.
52. 'Steeds weer kwam ik by Alexander de Grote uit, alsof hij zich in mijn hersenen als onkruid had vermenigvuldigd en de andere Alexander overwoekerde en verstikte.' Koubaa, *Het gebied van Nevski*, p. 46.
53. Koubaa, *Het gebied van Nevski*, p. 44.
54. '[A]lles wat u leest heeft in mijn brein gevochten voor de ruimte op deze bladzijden.' Koubaa, *Het gebied van Nevski*, p. 110. This remark is addressed to professor Van Nieuwenhuyze.
55. Koubaa, *Het gebied van Nevski*, p. 52.
56. '[...] literatuur [is] een seksueel gedreven soort afwijking van de evolutie! De taal is de staart waarmee de schrijver pronkt [...].' Koubaa, *Het gebied van Nevski*, p. 99.
57. Koubaa, *Het gebied van Nevski*, p. 66, p. 113.
58. 'En als ik niet meer ben dan de vier letters A, C, G, en T, waarvan de combinatie de machinetaal voor mijn constructie vormt, dan moeten mijn herinneringen en die van de stad daar ook mee kunnen worden opgebouwd, dan moeten mijn vingers het lied dat wij zijn kunnen spelen.' Koubaa, *Het gebied van Nevski*, p. 66.
59. 'Woorden die als een samengeraapt leger van boeren, vissers en ambachtslieden de opmars van het kwaad op de ijsvlakte tot staan brengen.' Koubaa, *Het gebied van Nevski*, p. 26.
60. Koubaa, *Het gebied van Nevski*, pp. 32-6, pp. 43-4.
61. '[...] Eigen Volk Eerst, een politieke slogan die er geen is omdat hij een oeroude sociaal menselijke eigenschap verwoordt [...].' Koubaa, *Het gebied van Nevski*, p. 93.
62. For a recent critical overview of these attempts see H. Rose and S. Rose, 'Darwin and After', *New Left Review* 63 (2010), 91-113.
63. F. Crick, 'Neural Edelmanism', *Trends in Neuroscience* 12 (1989), 240-8. For a recent defense and elaboration of Edelman's view see C. Fernando, R. Goldstein and E.

- Szathmáry, 'The Neuronal Replicator Hypothesis', *Neural Computation* 22 (2010), 2809-57.
64. G. Edelman, 'Neural Darwinism: Selection and Reentrant Signaling in Higher Brain Function', *Neuron* 10 (1993), 115-27 (p. 119).
 65. Edelman, 'Neural Darwinism: Selection and Reentrant Signaling', 115-27 (p. 117). See also Edelman, *Bright Air*, p. 83 and Joseph LeDoux, *Synaptic Self: How Our Brains Become Who We Are* (New York: Viking Penguin, 2003), p. 72.
 66. D. Swaab, *Wij zijn ons brein: Van baarmoeder tot Alzheimer* (Amsterdam: Contact, 2010), pp. 433-46.
 67. 'Wij komen ter wereld met hersenen die door een combinatie van onze genetische achtergrond en de programmering gedurende de ontwikkeling in de baarmoeder uniek zijn geworden en waar onze karaktereigenschappen, talenten en beperkingen al voor een belangrijk deel in zijn vastgelegd.' Swaab, *Wij zijn ons brein*, p. 447.
 68. 'The way the brains systems function determines which cells and connections will remain to exist. The brain cells struggle for life is called 'neuronal Darwinism'. [...] Multiple factors influence the brain in the early development stages. They decide, later in life, how we experience ourselves.' D. Swaab, 'We Are Our Brain: Brains, Consciousness and Faith – Neurobiological Aspect's', *Academy Magazine*, Fall 2005, p. 4.
 69. Edelman, *Neural Darwinism*, p. 126.
 70. Edelman, *Bright Air*, pp. 25-8; Swaab, *Wij zijn ons brein*, p. 27, p. 38, p. 51, p. 382.
 71. J. Ledoux, *Synaptic Self*; see also M. Sitskoorn, *Het maakbare brein. Gebruik je hersens en wordt wie je wilt zijn* (Amsterdam: Bert Bakker, 2008) and J.B. Arden, *Rewire Your Brain: Think Your Way to a Better Life* (Hoboken, NJ: John Wiley & Sons, 2010).
 72. *Avatar*, 0:13:30-0:16:00.
 73. P. Pisters, *The Neuro-Image: A Deleuzian Film-Philosophy for Digital Screen Culture* (Stanford, CA: Stanford University Press, 2012), p. 181.
 74. S. Ramón y Cajal, *Precepts and Counsels on Scientific Investigation*, ed. by C.B. Courville, trans. by J. M. Sánchez Pérez (Mountain View, CA: Pacific Press, 1953), pp. 147-8.
 75. L. Otis, *Membranes: Metaphors of Invasion in Nineteenth-Century Literature, Science, and Politics* (Baltimore / London: Johns Hopkins University Press, 1999), p. 85. Also see Kandel, *In Search of Memory*, pp. 61-65. To be sure, Ramón y Cajal himself actually rejected the contemporary notion that brain cells formed a continuous 'reticulum' (network).
 76. Edelman, *Bright Air*, p. 24.
 77. Edelman, *Neural Darwinism*, p. 170.
 78. Edelman, *Bright Air*, p. 27; Edelman, *Neural Darwinism*, pp. 133-6.
 79. *Avatar*, 0:53:00-0:54:18, 1:02:32-1:05:30.
 80. *Avatar*, 1:28:00.
 81. C.K. Yoon, 'Luminous 3D Jungle is a Biologist's Dream', *New York Times*, 18 January 2010. <http://www.nytimes.com/2010/01/19/science/1gessay.html> [last accessed 8 April 2013].
 82. F. Heylighen, 'Conceptions of a Global Brain: A Historical Review', p. 1. To be published in *From Big Bang to Global Civilization: A Big History Anthology*, ed. by B. Rodriguez, L. Grinin and A. Korotayev (University of California Press). For a brief history of the notion of the 'global brain' see C. Gere, 'Brains-in-vats, Giant Brains and World

- Brains: The Brain Metaphor in Digital Culture', *Studies in History and Philosophy of Biological and Biomedical Sciences* 35 (2004), 351-66.
83. Draaisma, *Metaphors of Memory*, p. 201. For Draaisma's discussion of connectionism also see pp. 185-211 in general.
 84. N. Carr, *The Shallows: How the Internet is Changing the Way We Think, Read and Remember* (London: Atlantic Books, 2010).
 85. K. Hillis, 'From Capital to Karma: James Cameron's *Avatar*', *Postmodern Culture* 19.3 (2009) http://muse.jhu.edu/journals/postmodern_culture/v019/19.3.hillis.html.
 86. See N.L. Stepan, 'Race and Gender: The Role of Analogy in Science', in *Feminsim and Science*, ed. by E. Fox Keller and H. Longino (Oxford / New York: Oxford University Press, 1996), pp.126-32.
 87. Choudhury and Slaby, 'Introduction', p. 10.
 88. Latour himself has pointed to this similarity in his 'An Attempt at a "Compositionist Manifesto"', *New Literary History* 41 (2010), 471-2.
 89. Choudhury and Slaby, 'Introduction', p. 10.
 90. Rose and Abi-Rached, *Neuro*, p. 23; also see pp. 216-9.
 91. In her analysis of Darren Aronofsky's film *The Fountain* (US, 2006), Patricia Pisters has described this kind of 'omnidirectional' Deleuzian enfoldings as an important characteristic of the 'neuro-image' in contemporary cinema (Pisters, *Neuro-Image*, pp. 186-214). It would be interesting to further investigate the relation of the 'neuro-image' in screen culture to the poetics of the neuromolecular gaze that I attempt to describe in this article.
 92. For the context of genetics such a project has been undertaken in S. Anker and D. Nelkin, *The Molecular Gaze: Art in the Genetic Age* (New York: Cold Spring Harbor Laboratory Press, 2004).
 93. Rose and Abi-Rached, *Neuro*, p. 148.
 94. Choudhury and Slaby, 'Introduction', p. 10.

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