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Educational neuroscience: Neuroethical considerations

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Research design and methods in educational neuroscience involve using neuroscientific tools such as brain image technologies to investigate cognitive functions and inform educational practices. The ethical challenges raised by research in social neuroscience have become the focus of neuroethics, a sub-discipline of bioethics. More specifically here, we give an overview of neuroethical issues arising from brain imaging studies and neuropharmacology in education, from neuromyths to potential stigmatization of learners, and discuss the relevance of establishing the field of educational neuroethics. We argue that by integrating ethical positions to research design and methods in educational neuroscience, it would become possible to contextualize results and the diffusion of results, which in turn insure better credibility among the wide variety of stakeholders to new knowledge emerging from educational neuroscience.

Keywords: educational neuroethics, educational neuroscience, neuroeducation, neuroethics

Introduction

Our cognitive capacities reflect distributed processes throughout the brain.
The thousand conscious moments we have in a day reflect one of our networks being up for duty.
When it finishes, the next one pops up, and the pipe organ-like device plays its tune.
What makes emergent human consciousness so vibrant is that the human pipe organ has a lot of tunes to play.
And the more we know, the richer the concert.
Michael Gazzaniga, 2007

We have limited understanding of the nervous system although knowledge is growing fast.
This limited knowledge partly explains the complexity of the ethical issues.
Eric Racine, 2010

Educational neuroscience is evolving at the interface of neuroscience, cognitive sciences and education, and even if education focuses solely on enhancing learning and the neurosciences solely on brain mechanisms involved in learning, the future of education and the neurosciences are tied together: educational practices are being and will continue to be transformed by science (Frith, 2011). Central to educational neuroscience and to its experimental design and methods is

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accessing real-time information about the brain that could shed light on cognitive functions, as defined by elements pertaining to learning such as the following: attention, memory, language, speech, emotion, consciousness, and other higher cognitive functions (Gazzaniga, 2004).

A central tool in research in educational neuroscience is brain-imaging using a variety of technologies, mainly hemodynamic, e.g., functional magnetic resonance imaging (fMRI) (Ashby, 2011) and electromagnetic, e.g., electroencephalography (EEG) (Ward & Doesburg, 2009). Although there is an abundant literature on the scientific challenge of individual methods of brain imaging technologies, such is not the case for ethical questions associated with the transfer of knowledge obtained from brain imaging methods to improve educational praxis. Through research in educational neuroscience, a variety of improvements in cognitive function and educational practices are envisioned, including increased attentiveness, memory, linguistic expression, mathematical and decision-making skills, and abilities to manipulate abstract concepts and mental images. We describe some concerns currently being addressed in the emergent field of neuroethics and argue for the need of an *educational* neuroethics in order to navigate around various pitfalls of knowledge transfer and exchange between neuroscience and education. For education, we believe this would more readily permit understandings of brains, minds and education as complex, dynamically developing systems.

Educational Neuroscience: Theoretical framework

What is the perceived status of educational neuroscience by practitioners of this emergent field? Byrnes (2001) describes quite clearly how the prevalent use of the computer analogy amongst teachers to describe human cognition can restrict educators from having much openness or curiosity toward new knowledge in neuroscience that could be relevant to their practice.

Moreover, the threat felt by some educators that neuroscientific data could only shed a reductionist light on what defines cognition is one of the main arguments put forward for restricting the flow of information between neuroscience and education. But is reductionism really the most fundamental threat? One could consider here that the still prevalent computer analogy is having an even more pervasive impact on interdisciplinary initiatives at the interface of cognitive science, neuroscience and education. The computer analogy basically presents the human brain as analogous to the hardware of a computer, with the mind as software, leaving cognition to be an input/output process, a view that constitutes the central paradigm of cognitivism. When the American philosopher Jerry Fodor (1974) formulated the argument that to think is to manipulate symbols, cognition was left to be nothing more than manipulating symbols the way computers do. This premise and Fodor's research inspired various functionalist approaches to cognitive science.

The functionalist view, issued forth in the 1950s from early cybernetics and according to which the mind is organized into specialized modules, reduces the brain to a syntactic device and not a semantic one. This is also true for the connectionist view and its neural network approach. Both paradigms retain somewhat dualistic notions of mental representation, and in doing so, contribute toward maintaining dualist distinctions between mind and matter, self and world.

These prevailing computational paradigms are preventing many educators from understanding that, as we enter the 21st century, neurosciences offer converging data supporting a radically new paradigm referred to as embodied cognition. Briefly, this radical view of embodied cognition (Varela, Thompson, & Rosch, 1991) emphasizes that our evolutionary continuity (we are essentially, like all animals, embodied agents), and our powers of advanced cognition, vitally depend on a substrate of abilities for moving around in and coping with the world that we inherited from our evolutionary forebears. This paradigm of radical embodied cognition implies that there is much more to cognition than the manipulation of mental representations: cognition is in constant interaction with the environment, creating emergent embodied structures to achieve cognitive tasks.

Having emerged from the collaboration of a neuroscientist (Varela), a philosopher (Thompson), and a cultural anthropologist (Rosch), radical embodiment is a striking example of profoundly unifying initiative in the traditionally disjoint fields of the sciences and humanities. As described by Thompson (2007): "Our mental lives involve our body and the world beyond the surface membrane of our organism, and therefore cannot be reduced simply to brain processes inside the head" (p. ix).

Radical embodied cognition has its roots in pragmatism, phenomenology and Buddhist philosophy (Varela, et al., 1991). According to this view, "cognitive moments emerge from the coordination of scattered mosaics of functionally specialized brain regions, a large-scale integration that counterbalance the distributed anatomical and functional organization of brain activity to enable the emergence of coherent behavior and cognition" (Varela, Lachaux, Rodriguez, & Martinerie, 2001). This description of cognition departs from the received views of cognition as symbol manipulation carried out in specific regions or networks of the brain (localism), and offers an inclusive view where the symbolic level is acknowledged but the governing principles happen at a subsymbolic level. A parallel can be draw here with another shift in paradigms, in biology, regarding our understanding of the so-called genetic code. For the longest time, biologists have considered protein sequences as instructions coded in DNA. It now appears that DNA triplets are capable of specifying an aminoacid in a protein *only* if they are operating as part of the cell's complex chemical network. It is because of the emergent regularity of the network as a whole that we can be led to think that the triplets *are* the codes for aminoacids. In short, they, the triplets, are not independent of the substratum from which they emerge (Varela, et al., 1991) just like specialized brain regions are part of a large-scale integration from which coherence is an emergent property.

Phenomenology, in tandem with dynamic systems theory, as integrated in the work of Varela (Varela, et al., 2001), Thompson (2007), Noë (2009), Gallagher (2002), and Zahavi (2010) on embodied cognition also reaches deeply into the work of analytical philosophers such as Clark (2008). For Clark, a mature science of the mind should target not only the individual inner organization but also the bodily and environmentally extended contexts responsible for adaptative success. Clark's example of the bluefin tuna's puzzling swimming ability offers a good example, as the aquatic capability of that fish has long mystified biologists. The structure of the fish was simply too weak to explain its performance. But an explanation can be found in the use of embodied, environmentally embedded action by the tuna: the tuna finds and exploits naturally occurring currents, and uses its tail flap to create additional vortices, which are then used by the bluefin tuna for rapid acceleration and turning. From there, Clark argues that bodies, by incorporating, rather then merely using external tools, can extend beyond the organism's boundaries, something that he also applies to cognition. For example, is my iPhone part of my extended mind? If the notion seems highly debatable at the philosophical level, reports of neural correlates of Early Stone Age tool-making and cognition in human evolution are showing how human brains and technologies have been co-evolving for at least the last 2.6 Myr, when the first intentionally modified stone tools appeared (Stout, Toth, Schick, & Chaminade, 2008). For Stout, et al., according to this evolutionary perspective, understanding the brain bases of complex tool-use and tool-making emerges as a key issue for cognitive neuroscience. Moreover, the question of how we come to experience unified cognitive moments from the coordination of scattered groups of functionally specialized brain regions was simultaneously tackled by different teams of neuroscientists, and various models have been proposed, all involving the aspects of large-scale integration, either by phase synchronization (Varela et al., 2001), transient synchronization (Fingelkurts & Fingelkurts, 2001), or temporal binding (Engel & Singer, 2001).

For educational neuroscience, radical embodiment implies rethinking of cognition less in terms of representationalism and computationalism, and more in terms of the action of an organism in its world (Campbell & Dawson, 1995; Chemer & Heyser, 2009). It does not suffice to say that the brain is the main organ of learning to justify opening the door to neuroscience in education. Furthermore, if there is a common acceptance of the crucial role of biology in every aspect of the human experience, it does not necessarily follow that biology determines its outcome, but there is a definite need to come up with new methodologies to test the effects of educational interventions (Goswami, 2008).

How do we proceed to integrate this shift in ontology? We suggest that by considering mind and brain different aspects of a unitary ‘mindbrain’ warrants a search for correlations between subjective experience and embodied behavior, all the while steering clear of both idealist (thinking only in terms of mentation) and materialist (thinking only in terms of mechanisms) views (□redacted□)--each comprising one side of the Cartesian ontological divide (□redacted□)--and recognizing the experience of the learner, a perspective that has to be kept in mind when designing research protocols in educational neuroscience. It follows from the perspective of radically embodied cognition, that subjective experience must, in principle, manifest objectively in some manner or other as changes in brain, body, and behavior, and vice-versa (□redacted□), such as is apparently suggested in a recent study on loneliness, where Cacioppo has established that it is actually the subjective experience of loneliness that is harmful (physiological impact), not the actual number of social contacts a person has (Cacioppo, 2010).

Based on a well-defined theoretical framework, neuroscience has much to offer to our understanding of learning processes. In the view from neuroscience, learning is often synonymous with memory. It is generally accepted that we have multiple memory systems, and that learning, in terms of formation of memory, occurs by changes in patterns of connectivity between neurons (viz., synaptic, neural, or brain plasticity). Learning involves important structural changes in the brain, and when learning actually occurs, there is a shift in patterns of activity within brain networks (Howard-Jones, 2008). For educational neuroscience, the effects in brain connectivity and behavior in response to educational intervention is guiding learning assessment as demonstrated by recent findings. Examples of instructional applications of neuroscientific data are becoming more and more in tune with educational challenges: Dumbar’s work (2005) using brain and behavior is shedding light on how changes in concepts take place, and represents a convincing example of instructional application of neuroscientific data. The investigation of the mechanism of *active inhibition* of old information by Potvin, Riopel and Masson (2009) using fMRI, points to the combined roles of the anterior cingulate cortex and the prefrontal cortex, both being well known for their excitatory and inhibitory functions. In the case of the anterior cingulate cortex, it is generally proposed that, since there are large spindle neurons in layer Vb, the anterior cingulate cortex could play a central role in the adaptive response to cognitive dissonance.

Further illustrative of the educational relevance of neuroscientific investigations can be found in the works of Cohen, Vinckier, and Dehaene (2010) on dyslexia, Schlaggar and McCandliss (2007) on auditory and visual language perception and Butterworth (2008) on dyscalculia. The work of Delazer (2005) comparing memorization conditions and strategic conditions of learning novel arithmetic operations, have led to a more fundamental understanding of the classic educational statement according to which ‘different learning contexts can lead people to adopt different strategies to solve the same problem. Another interesting example with her recent results suggests that fraction might be represented by its numerical value as a whole, rather than by the numerical values of its numerator and denominator (Ischebeck et al., 2009).

More generally, examples such as those presented above tend to confirm the neuroscientific ground of the affirmations that learning is incremental and experience-based, that learning is multi-sensory and that brain mechanisms of learning generate and modify structure in response to stimuli and reflection. Furthermore, as we have seen up to this point, applying neuroscience findings to topics in education requires proper conceptualization of the relation between cognition and the brain function (Varma & Schwartz, 2008), otherwise efforts and innovation become entrenched in misconceptions and neuromyths. One of the more crucial steps educational neuroscience, neuroeducation, or more general studies pertaining to mind, brain, and education (Campbell, 2011), has to take, for instance, is not to be blinded by unspoken affirmations that neural correlates imply causation. However, in the currently predominant language of achievable goals, benchmarks, or assessable standards (De Ruyter, 2006) in education, is there a risk that we might have already fallen into the narrow trap of a "brain-based education"?

Neuromyths in education

Neuromyths could be simply defined as dubious claim made from naive uses of brain images. The central tool of research in neuroscience, functional neuroimaging, gave researchers unprecedented access to the behaving brain, and its technical development in the 90's launched what would be called in the United States the 'Decade of the Brain". The diffusion of neuromyths itself of neuromyth is particularly revealing of the need, for educational neuroscience to identify and establish theoretical and philosophical foundations, a challenge that comes with emergence of any new discipline but made more complex in this case by the cross-disciplinary nature of the enterprise (□redacted□).

Naive interpretations of functional neuroimaging are often the starting point of neuromyths. If a popular saying tells us that an image is worth a thousand words, it is not the case of brain images that required, to the contrary, more than a thousand words to extract their meaning.

In the case of EEG, the recording of electrical signals emanating from the human brain provided data which can be collected from the scalp of the head with very low inertia, a method well tuned with the speed of elementary cognitive act (Fingelkurts & Fingelkurts, 2006), but that typically requires statistical analysis in order to extract meaning from data. Since signal-to-noise in brain imaging is generally poor, the statistical validation of results becomes decisive. But as pointed out by Doesburg, Roggeveen, Kitajo, and Ward (2008), phase synchronization between two neural sources indicates that information is in all likelihood being exchanged between those sources, but often it is not enough to infer causality. In order to overcome these limitations of data analysis, new statistical tools are being developed (Bressler & Menon, 2010).

In the case of fMRI, signals arise from changes in local oxygen uptake (brain demand for oxygen) resulting from neural activity. If the central assumption guiding inference in this case is the linear transform model which states that fMRI signal is appreciatively proportional to a measure of local neural activity average over a period of time of several seconds, it is not without its own methodological questions (Heeger & Ress, 2002), being often accused of generating color pictures of the brain that give the illusion of explanatory depth. This pervasive influence also had impact on the public/parents, and is worthy of attention. In their study of the effect of brain images on judgments of scientific reasoning, McCabe and Castel (2008) have asked participants to rate the quality of articles on cognitive neuroscience where data were either accompanied by brain images, accompanied by other representations of data, or by no representations at all. The data accompanied by brain images were judged as the most reliable even if they were not relevent, a tendency that may be related to people's natural affinity for reductionist explanations of cognitive phenomena.

So it appears that these images of the brain simply struck the imagination and brought about simplistic causal relations from correlate of brain activity and behavior, or in other words, localism, which has little purpose in education: knowing the localization of cognitive function for the sake of mapping the brain is of no use whatsoever to improve educational practices.

Uttal (2003) argues that many neuroscientists might have gone off without careful consideration of the potential conceptual problems lying just below the surface of the entire localization enterprise. As well demonstrated by Geake (2008), what ensued was a series of neuromyths that invaded educational practices at an incredible speed: ranging from left and right brain thinking, multiple intelligence, visual auditory kinesthetic learning styles and so on. What makes teachers adopt pigeon-hole approach, or so-called brain-based method when their daily classroom experience only reveals learners' individual differences? On the part of the neuroscientific community, there is a well-documented need to improve communication skills by a cultural shift that would explicitly recognize and reward public outreach (Illes et al., 2009). For practitioners in education, there is a need to rethink teacher education programs to face the fact that at the current time, neuroscience has developed to the point where it is having increasingly marked effects on society, extending far beyond laboratories, reshaping our understanding of our biological foundation, transforming our understanding of cognition (Farah, 2005).

As researchers and educators are working to bring advances from neuroscience and cognitive science into educational research and practice, ethical issues connected to methods and applications in education are emerging and require attention. We will here provide an overview of the most present neuroethical concerns in education.

Neuroscience and ethics: introducing neuroethics

What are the challenges faced by educators that are brought about by educational neuroscience and more generally speaking educationally oriented neuropharmacology? Let's first consider a few vignettes: I am the parent of a 10 year-old boy who received a diagnosis of dyslexia last week. Why hasn't the school provided the early detection tools now available? I am an undergraduate student and I want to report that, during last Calculus exam, five of my friends were under the influence of high doses of methylphenidate (i.e., Ritalin). Is that fair? I am a primary school teacher and the parents of one of my students came to me asking for a special program for their child based on brain scan images. What do I tell them? I am a pre-service teacher and I don't know what to think of this brain-based education movement. Are some of my students really using more of the right side of their brain? I'm a high school physics teacher and I often wonder what it is, in the way we learn, that makes naïve theories so resistant to change?

These issues are currently debated in the field of neuroethics, a term which appeared in the work of Churchland, (1991) in philosophy of neuroscience, but that fully entered the academic sphere in 2002 (Marcus, 2002, Roskies, 2002, Fukushi & Sakura, 2006, Levy, 2007) to give a name to the "field of philosophy that discusses the rights and wrongs of the treatment of, or enhancement of, the human brain" (Marcus, 2002). As a subfield of bioethics, it has since then been generating an important body of scientific literature.

Neuroethics is taking shape more than three decades after Van Rensselaer Potter introduced the definition of bioethics as an attempt to promote the integration of biology and humanities. If bioethics mainly took a turn toward biomedical ethics, leaving aside the Potter naturalistic approach, it was not the case in neuroethics, which have been taking a strong step towards the two-way relationship between life science and the humanities (Racine, 2008), and in the present case, neurosciences and education. But in fact, neuroethics goes further than a simple bioethics for the brain in the way it addresses issues deeply embedded in our understanding of what makes us human, exposing still deeply embedded dualistic views distinguishing between brain and mind.

In trying to define neuroethics, it is important bear in mind the two distinctive branches of neuroethics: the ethics of neuroscience, which is our concern here, and the neuroscience of ethics (Illes, 2006). Neuroscience of ethics (Churchland, 1998), for its part, embraces the growing findings about the neural bases of moral agency and is not of our concern in the current discussion. We will consider, first, potential neuroethical issues generated by research methodologies in educational neuroscience and second, those regarding applications, like cognitive enhancers, that are part of a series of educationally oriented neurotechnology such as neuropharmacology aiming at cognitive enhancement, neurofeedback, and brain-machine interface, to name a few, that are making their way into the classroom

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Educational neuroscience: neuroethical consideration on methods

Educational neuroscience involve by definition research on human subjects. Beyond the fundamental ethical standards for human subjects that guide academic research (Ravitsky, Fiester, & Caplan, 2009), some questions are arising that are specific to the neuroimaging methods associated with educational neuroscience research (J. Illes, Tairyan, Federico, Tabet, & Glover, 2010). If there are obvious questions in the more general field of neuroscience regarding some cases of 'instant science' versus peer-review as in the data of Iacoboni in neuromarketing, (Iacoboni, 2006), some questions definitively pertain to educational neuroscience (Giordano & Gordijn, 2010; Farah, 2007) such as incidental findings, predictive and diagnostic applications, commercial applications, selective publishing and issues of issues of fair access. If neurosciences have provided insight into numerous neurological disorders and hold great promise in understanding cognitive process, concerns about the risk of various neuroimaging modalities are mounting (Downie & Marshall, 2007**).** I will present in more detail the four following aspects of ethical concern: consent, confidentiality, stigmatization and incidental findings.

Consent: surrogate decision-making

The fact that it is generally designed to gain generalizable knowledge that may benefit others in the future, but not necessarily the participants taint the basis for surrogate decision-making in educational neuroscience research. The parents are required to use the best interest of the child as the basis for their decision-making. What is the risk of misconceptions by the parents of non-therapeutic research investigating cognitive functions? Even if applications of the general knowledge can be further used to assess the effectively of educational interventions (e.g., dyslexia), it remains that parent education regarding the aims of research is an important consideration to be dealt with as part of informed consent.

Confidentiality

When using neuroimaging in neuroeducational research personal information about the child may be required either to ensure the safety of the participant or to meet some predetermined exclusion criteria. What will happen if schools have interests in the results?

Stigmatization

A value-laden language is sometime present in neuroimaging studies to describe various brain structures and functions, even thought normal brain anatomy and functions have yet to be determined. What if such a 'diagnostic' terminologies transfer pejoratively to educational practices? A modicum of intellectual humility is always called for to honor the uniqueness of individuals beyond the normative construct of "normality".

Incidental findings

Detecting an unexpected pathology is not limited to educational neuroscience research, but is nonetheless a reality, not to mention the risk related to Type I & II statistical errors. It presents a practical and ethical challenge to neuroimaging researchers, and very few guidelines currently exist. Potential risk and adverse events also have to be included in those ethical considerations. As suggested by Stein and Fischer (2011), knowledge emerging from educational neuroscience must have practical value that is able to be put to good use (viz. it must be "usable" knowledge), and its application and dissemination ought to be infused with moral considerations gleaned from the exchanges among all those potentially affected.

Educational neuroscience: Considerations regarding applications

In North America, students are increasingly using prescription drugs in order to provide cognitive enhancement and thereby support their studies (Howard-Jones, 2010). Nootropics, or smart pills i.e., neuropharmaceutical products developed to treat brain-based disorders have been making their way into schools, preying on students' belief in a somewhat mindless magic bullet toward self-managing their brains. Drugs such as *piracetam* (memory), *modafinil* (wake-promoting) and, in most cases, *methylphenidate*/Ritalin (attention) are used more and more for enhancement in healthy people.

Even if, as it turns out, neuropharmacology doesn't yet deliver more than temporary attention enhancement, the current use of nootropics and the next generation of smart pills to come will continue to cross the boundaries of therapy to enhancement and into the still widely unexplored territory of human cognition, raising numerous ethical issues in education. This phenomenon, that could limit itself to be discussed under the paradigm of prescription drug abuse, is more currently included in the paradigm of cognitive enhancement or performance enhancement offered by neuroscience to increase cognitive functions beyond what is considered necessary to sustain or restore good health. The obvious ethical challenge to education comes from the fact that such non-medical use of nootropics is somehow viewed as a lifestyle choice, as revealed by the common comparison of *Ritalin* to classic study tools such as tutors and caffeine pills, although that lifestyle choice is admittedly made in response to tremendous social pressure to perform in a competitive environment marked by the search for quick fixes (Racine & Illes, 2008).

The first question to address in order to sort out the facts from the hype in trying to make sense of the increase use of nootropics is to question the extent of their ability to improve our short- and long-term memory or our executive functioning, those cognitive systems that oversee processes involved in planning, abstract thinking, inhibiting action, and so on. The term nootropics was coined in 1964 by Corneliu Giurgea after the synthesis of *piracetam*, in order to describe a new category of molecules that were characterized by a direct functional activation of the higher integrative brain mechanism. Nootropics launched a new the field research, setting out to find new drugs capable of enhancing directly the efficiency of the cognitive activity of the brain, with the objective of compensating various neurological deficits related to aging. Their non medical use leads to cognitive side-effects that fall into three main categories: first, as cognition-enhancing drugs they can simultaneously exert both linear and quadratic (U-shaped) effects, doses most effective in facilitating one cognitive function could at the same time exert no, or even detrimental effects on other cognitive domains; second, individuals with 'low memory span' might benefit from cognition-enhancing drugs but 'high span subjects' are overdosed; finally, evidence suggests that a number of trade-offs occur where, for example, an increase in cognitive stability might come at the cost of a decreased capacity to flexibly alter behavior. Another aspect coming to light is the fact that nootrops do not improve retention of learned information. (Grön, Kirstein, Thielscher, Riepe, & Spitzer, 2005).

The major societal issues of nootropics have been described by Illes (2006) as forming four main categories of ethical challenge: safety, coercion, distributive justice and personhood. She readily admits that in the ethics of neurocognitive enhancement, we are 'still feeling our way towards relevant principles'. The questions arising are forcing us to revisit our diverse ethical premises: does hard work confer 'dignity'? Am I the same person when on Ritalin? As it appears, there is more involved here than rules and regulations. The use of nootropics is spreading on the *belief* alone that it will provide improved performance. The working market expectation of having people wired day and night is an obvious coercive force, and a subtler but no less pervasive one would be the simple fact of teachers finding enhanced children more receptive to learning and interacting differently in that context. On the other hand, restricting the use of nootropics is in itself also coercive, removing people of their freedom of choice to enhance or not. Distributive justice also has to be addressed, since it obviously creates an unfairness between haves and have not's. With society already being full of such inequities, from private tutoring to cosmetic surgery, it is not an issue specific to nootropics until we add to it the question of cheating. To question if enhancement in itself is a form of cheating is a more specific reality of nootropics than inequities.

Cheating, as a matter of fairness, carries *de facto* moral wrongness when defined as the breaking of implicit rules or the access to unfair advantages. Most discussions on the unfairness of enhancement have emerged for competitive sports, since performance enhancement is the intrinsic goal of sports (Schermer, 2008). In this case, it is addressed by changing rules and instituting controls and sanctions, as well as an endless reassessment every time a new form of enhancement comes around, based on: safety, possible fair access to all athletes, respect of constitutive rules of the sport (doing a marathon on roller blades by removing the running aspect to the marathon would be breaking a constitutive rule of that sport) being the main criteria of those reassessment. Also tricky is the notion of deserved victory based on merit or natural abilities, which could include the smart use of technologies.

The list of what can be described as social risk to which educators are especially called upon is getting longer by the day and advances and new understanding at the interface of neuroscience and education can rapidly translate into policies and decision making having major ethical implications. If educators and scientists, or educators amongst themselves are divided in redefining their value system in neuroethical terms, the debate will transit into the public sphere where they will both, educators and scientists, have to clarify their respective assumptions and frameworks.

As the capacity for spatial and temporal resolution of structural, functional and electrophysiological imaging technologies improves, it is expected that there will be better resolution in measuring and brain activity. In time, it is also expected that with the increasing efficiency of computing technology, it will be possible to provide calculations related to cognitive activity in near-real time These are all good news for educational neuroscience (Deslauriers et al., 2010), if supported by a clear ethical framework for both researchers and practitioners in the field. If sufficient justification already exist for the relevance of neuroethics in education, (Sheridan, Zinchenko, & Gardner, 2005), there are likely further issues pertaining to educational neuroethics not discussed here (e.g., questions concerning access; effectiveness of interventions versus control groups) and others yet to be recognized.

Conclusion: The need for an *educational* neuroethics

What do we already know about learning and the brain? What do we need to know to better understand cognition? How can we communicate this knowledge effectively amongst educators, parents and researchers? The challenges of applying neuroscientific findings in education are numerous, but have a common denominator: the framework supporting neuroeducation has to be well defined and explicit. Neuroscience is not only developing under a very reductionist program but also more openly under the paradigm of radical embodiment (Thompson & Varela, 2001), an approach that support our phenomenological sense of experiencing life and offering a platform to be able to think between disciplines, across disciplines and beyond existing disciplines. toward new ones (Campbell, 2011).

Education, according to its intrinsically utopian or idealistic nature, is constantly reassessing its conception function and values. But things have not gone too well in the early attempts of transfer between neuroscience and education: oversimplifications and a lack of conceptualization led, in the 90’s to the development of a so-called brain-based education that brought into the classroom an array of neuromyths that are still resisting revision today. These neuromyths came in part from the general fascination over the images provided by the brain imaging tools of neuroscientific investigation. It was easy to think of these images of brain-in-action as open windows on cognition: in a functionalistic approach, lifting the hood was going to reveal the process, and correlation would be established without paying too much attention to causation. But brain images have to be recognized for what they are: Mere tools, with statistical value providing an echo, a glimpse at something much larger and more subtle within ourselves.

Just as neuroethics took shape because the specific issues related to neurosciences were distinct from issues generated by the field of genetics and the accompanying bioethics in the 70s (Roskies, 2009), the ethical issues faced by educational neuroscience fall under at least two distinct types: first, those that are inherited from other areas of ethics (e.g., bioethics, medical ethics); and second, those that are unique to or generated by the field of educational neuroscience and other more general areas of concern to mind, brain, and education (Stein & Fischer, 2011).

If critics of the relevance of subdisciplines of the broader philosophical field of ethics are concerned with the potential risk that such subdisciplines could be distracting and thus obscure rather than qualify the analysis of pressing ethical issues (Wilfond & Ravitsky, 2005), we argue here that to the contrary, a subfield of educational neuroethics would ensure, as illustrated by the case of imaging studies involving children in educational neuroscience research (Illes, 2010), the rapid development of an ethical framework in support of the transfer and exchange of knowledge between these vast fields of neuroscience and education. *Primum non nocere* or ‘*Above All, Do No Harm*’ is not enough (Smith, 2005): educational neuroscience needs to elaborate guidelines based on common values to inspire research design in the field. If we do not wish to transit from personhood to brainhood, there are frameworks that offer unified views of our embodied mind, expanded, in constant elaboration and resonance with the world (Campbell, 2010, 2011).

In essence, we have argued here that since education is a truly transformative process, educational theorists, researchers, and practitioners alike have a leading role to play in the development of a mindful, radically embodied *educational* neuroethics.

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Eğitsel sinirbilim: Sinirsel etik üzerine düşünceler

Eğitsel sinirbilimdeki metotlar ve araştırma dizaynı, bilişsel fonksiyonları araştıran beyin imaj teknolojileri gibi sinirbilimsel araçları ihtiva eder ve eğitsel uygulamaları bilgilendirir. Sosyal sinirbilimdeki araştırmalardan kaynaklanan etik sorunlar biyoetikin bir alt disiplini olan siniretikin odağı olmuştur. Burada, nöroefsaneden öğrenenin potansiyel stigmatizasyona kadar uzaman eğitimdeki nörofarmakolojisine ve beyin görüntüleme çalışmalarından kaynaklana nöroetiksel konulara bir genel bakışı ile ele alarak eğitsel nöroetikin alanının belirlenmesine ilgisi tarışılacaktır. Eğitsel nörobilimdeki metotları ve araştırma dizaynını etik pozisyonlara entegre ederek tartışıyoruz, böylece eğitsel nörobilimden çıkan yeni bilgileri geniş ve çeşitli paydaşlar arasındaki güvenirliliği garanti ederek sonuçların yayılması ver kavramsallaşmasını mümkün olacaktır.

Anahtar kavramlar: Eğitsel nöroetik, nöroeğitim, nöroetik