Issues with the Uses of Functional Magnetic Resonance Imaging (fMRI) in Education

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Functional magnetic resonance imaging (fMRI) has transformed the empirical study of the human mind in the 21st century in a fundamental way. The groundbreaking research involving the use of fMRI brought a variety of arguments on what fMRI can and cannot tell to ethical, legal, social issues and the implications of use of such technology in many domains including education (see Berker, 2009, Celone & Stern, 2009; Greene, Sommerville, Nystrom, Darley, & Cohen, 2001 and Raizada, & Kriegeskorte, 2010). Despite the abundance of studies either utilizing fMRI or addressing fMRI, the issue of the use of fMRI is continuing to be a vigorous area of research.

fMRI is a non-invasive brain imaging technique that does not involve radiation (Byars, Holland, Strawburg, Bommer, Dunn, Schmithorst, & Plante, 2002). fMRI has opened a new window into neuroimaging by attempting to provide real time information on the functions of the brain. It is based on a technology, which provides functional maps of the working brain by tracking changes in the magnetic signals resulting from oxygenated and deoxygenated hemoglobin (Gligorov & Krieger, 2010; Ogawa, Lee, Nayak, & Glynn, 1990; Vanmeter, 2010). This method is known as BOLD (Blood Oxygenation Level Dependent). Neural activation produces a physical effect on red blood cells by moving them from a state of oxygenation to deoxygenation (Cumming & Ramsey, 2009). While the magnetic field produced by oxygenated hemoglobin has almost no effect (or no effect) on the MRI signal, deoxygenated hemoglobin has a weak effect on the MRI signal (Vanmeter, 2010). Even though changes in such signals are very small, they can be detected while the subject is performing cognitive tasks (Celone & Stern, 2009; Ogawa, Lee, Nayak, & Glynn, 1990). Here, fMRI attempts to pair the neural activity with local cerebral blood flow. The changes in the blood flow are associated with the task the individual is engaged in (Craighead & Nemeroff, 2001).
The groundbreaking research involving the use of fMRI has brought a variety of arguments from what fMRI can and cannot tell, the implications of the use of such technology in many domains including education, and to the ethical, legal, and social issues with regard to fMRI. Such possible implications of the use of fMRI are under question due to the validity issues regarding fMRI findings.

1. Concerns with regard to the validity of fMRI

1.1. Equating structure and function

Just because there is some activity in the certain structure of the brain, does this really mean that specific parts of the brain are involved in the function? Another question being raised is: “Does this activity mean that the certain structure of the brain alone is responsible for such function?” (Racine, Bell, & Illes, 2010; Rosen & Gur, 2002; Illes, Racine, & Kirsch, 2006). A false activation which can be caused by ordinary things like eye-blink (see Desmond & Chen, 2002) or movement during fMRI scanning can pose a problem to the validity of fMRI findings. Special types of statistical analysis are required to eliminate such distortion of the fMRI results (see Racine, Bell, & Illes, 2010 and Vanmeter, 2010) otherwise the validity of the result would be questionable.

1.2. Accurate reference point for normal brain structure and function

Due to the non-quantitative nature of fMRI results, comparison of the results obtained from more than one task is required (VanMeter, 2010). The accuracy of the reference point is a necessity for any comparison, intrapersonal and interpersonal. The question is “do we have an accurate reference point for normal brain structure and function?” For instance, functional imaging can produce different results based on the technique it utilizes; oxygen consumption (fMRI) versus glucose utilization (PET) (see, Fox, & Raichle, 1986; Fox, Raichle, Mintun, & Dence, 1988). “The BOLD contrast mechanism reflects the input and intracortical processing of a given area rather than its spiking output” (Logothetis, Pauls, Augath, Trinath & Oeltermann (2001, p.150). Namely, while an fMRI signal detects the input in the local field, it does not detect total output with regard to the stimulus (Kosik, 2003). There is vagueness concerning reference point information when attempting to address this issue (Santosh 2000 and Wilke et al. 2003 as cited in Fenton, Meynell, & Baylis, 2009). Without a solid reference point, the validity of fMRI findings would be questionable.

1.3. Brain plasticity

Given the fact that the brain has plasticity, meaning lifelong capability of the brain (1) to adjust itself (i.e., physically, chemically or physiologically) to the changes that occur in the environment and (2) to recompense for brain trepidation, including damage. One thing to remember about plasticity is that it takes place in ways that are not foreseeable. This means, the same experience may affect the brain in different ways (Kolb & Teskey, 2011) intrapersonal and interpersonal. This raises a question of the validity of the fMRI results obtained from children (in terms of making function-structure association) due to rapidly changing characteristics of a child’s brain.
1.4. Subjective perceptions of qualitative data

The question raised by Hanan A. Alexander (2006) needs serious attention as we make further moves with fMRI and its educational implications: “how educational researchers can believe the subjective perceptions of qualitative participant-observers given the concern for objectivity and generalisability of experimental research in the behavioural and social sciences” (p. 205).

1.5. Post hoc ergo propter hoc

Just because there is activity in certain parts of the brain immediately after the cognitive task has been performed, can we say that task and activation are related or have a causal relationship? The answer to this question is “not always,” which brings us the fallacy of post hoc ergo propter hoc issue (J. Giordano, personal communication, July 2011). Post hoc ergo propter hoc means “after this, therefore because of this” in Latin, which refers to an erroneous logic of causation between two events by the faulty conclusion that an event is caused by another event simply because it came after it. Namely, if X occurs after Y, then Y is the cause of X. Just because something is followed by something else, does not necessarily mean the former caused the latter (Copi & Cohen, 1990; Lerner, 2002; Schmookler, 1999). Even though there are statistical techniques for preventing such fallacy of indicating a cause-effect sequence, yet, “unfortunately the number of variables involved usually vastly exceeds the number of equations to be worked with, which means that analysis can yield no certain answers” (Hardin, 1993, p.192).

1.6. Uniqueness of cognitive strategies

Because each individual is unique, individuals may use their brain in different ways. This means, the activation in the brain of one individual might be quite different or take place in different parts of the brain compared to another individual who is involved in the same cognitive task.

1.7. Statistical analysis of fMRI data

Statistical analysis employed to correct the motion artifacts, setting the threshold for a general linear model regression, comparison of several tens thousands of statistical analysis, and obtaining false negatives and/or false positives pose a serious concern with regard to the accuracy of mapping brain function attained from such complex analysis (Racine, Bell, & Illes, 2010). The changes in results of fMRI not related to the cognitive task the individual is experiencing (i.e., number of hours of sleep before the experiment, Habeck et al. 2004 as cited in VanMeter, 2010) can pose a problem with regard to the interpretation of the data.

2. Issues with regard to use of fMRI in education of children

What are the possible uses of fMRI in education? Some possible uses of fMRI in the educational system are (1) to identify students whose education could be promoted by offering additional resources that are more appropriate to their ‘perceived’ cognitive abilities (i.e., exceptional learners); (2) to channel students into more appropriate programs based on their cognitive abilities; (3) to identify children with potential troublesome dispositions (i.e., violent) (Celone, & Stern, 2009; Fenton, Meynell, & Baylis, 2009). The question here is whether or not fMRI can provide more...
accurate results than what is currently done with psychological and behavioral testing for diagnosing purposes. Even though, currently, the answer to this question is unclear, in the near future, validity and interpretative issues with regard to fMRI may be improved.

One of the main issues regarding the use of fMRI in education is that the use of such technology may lead to categorization of children based on their neural mechanism. Such categorization relies on the assumption that all children use the same neural process when they are learning. This assumption simplifies the learning process as there is more than one way of learning the same subject/topic. Focusing on a single component that is involved in learning (i.e., memory), reduces learning process to a component of learning (Pierce, 2009). This brings the issue of mereological fallacy (J. Giordano, personal communication, July 2011), which refers to the logic of establishing a relationship between parts and the whole in a way that regards a part as if it is the whole (Maslin, 2007). Referring to a study skills booklet, Maslin (2007) gives an example for such fallacy. According to this booklet, the left hemisphere of the brain thinks with words, while the right hemisphere thinks with images and pictures. Maslin argues that such claims are meaningless as they attribute cognitive activities to “the brain considered as a whole, much less to parts of brains” (p. 211). This fallacy becomes especially problematic in studies dealing with neuroscience. ¹ Similar to this fallacy, reductionism as labeled by Bennett and Hacker (2003), also poses a problematic view on the learning process. For instance, according to Francis Crick (1995):

“The scientific belief is that our minds—the behavior of our brains—can be explained by the interactions of nerve cells (and other cells) and the molecules associated with them.* This is to most people a really surprising concept. It does not come easily to believe that I am the detailed behavior of a set of nerve cells, however many there may be and however intricate their interactions” (p.7).

Along with these simplifications with regard to neural/cognitive process, categorizing children based on their neural mechanism, these assumptions disregard individual differences in learning. As it is clear for educators, individual differences in learning varies greatly; while some are visual learners others are auditory learners or kinesthetic learners, to name a few. Based on their learning style, individuals may use different neural pathways in the process of learning.

Would categorizing children based on their neural mechanism lead to biological determinism? To answer this question we need to answer the following question “what does such categorization entail?” It entails the idea that the biological process alone shapes neural mechanism. This brings us the definition of biological determinism. Biological determinism, sometimes called genetic determinism, refers to the idea that

¹ According to Bennett and Hacker (2003), assigning psychological attributions, (i.e., thinking, believing, interpreting, inferring, knowing, reasoning, deciding), to the brain or a part/section of a brain (i.e., the hemispheres or even neurons) are rooted from Cartesianism, and are far from scientific claims, rather philosophical claims. For a detailed discussion of the mereological fallacy in neuroscience, see M. R. Bennett and P. M. S. Hacker’s (2003) Philosophical Foundations of Neuroscience. Malden, MA: Blackwell Publishing.
human characteristics and behaviors are shaped only by genes (De Melo-Martin, 2005). It is well known that biology is not the only factor affecting the structure of the brain. Experience also shapes the biology of the brain. For this reason, neuroscience cannot or should not lead to a biological determinism (Farmer, 2010). If the brain is changing based on the factors rooted in the environment, then, the idea that genes alone are responsible for human behaviors become meaningless.

Even though embracing neurotechnology does not necessarily lead to biological determination, this does not mean that neurotechnologies (including, but not limited to fMRI) will not be used to categorize children or adults. Neurobiological determination of social/practical categories, namely “neural norming,” may lead to “Euneuromics,” meaning neurologically based “good” or “well.”

Another issue regarding the use of fMRI in education involves the economical feasibility of utilizing such technology in educational settings. Given the economical difficulties facing today’s educational system, how feasible is it to utilize such technology in educational settings? The answer to this question is tied closely to the validity, reliability and usefulness of fMRI. The more studies conducted to address and eliminate such issues, the easier and more acceptable it would be to use fMRI in many different settings including educational settings. Once the main issues with regard to the interpretative difficulties are addressed properly and solutions are provided, the doors to common use of fMRI would be opened.

2.1. Parental consent issues

Parent consent issues mainly revolve around health, safety, and privacy concerns. Because fMRI is a relatively new technology, its long term effects on the brain are simply unknown. Just because this technology does not involve ionizing rays, does it make it safe, especially for children whose brains are rapidly changing? Because of the possibility that children’s forming brains might be at danger, it raises ethical concerns. Would it be ethical for parents to give consent for non-clinical use of fMRI on their children given the possibility of negative effect(s) of such technology? Another issue regarding the parental consent is if it is ethical for parents to not give consent for non-clinical use of fMRI on their children, which may limit their children’s access to the best educational/health practices. Do parents have rights to deprive their children from a technology that could benefit their children’s education? What is the future of parental consent if fMRI becomes a widely used technology? Would we still need parental consent? Considering that parental consent is not needed to test children in school because it is a widely used practice, will fMRI be perceived as a common practice in the near future (J. Giordano, personal communication, July 2011)?

Use of fMRI can also be perceived as invasion of privacy of young children who are unable to make a judgment about such technology. Do parents have the right to let their children be brain-scanned even if it involves invasion of privacy? Would we, adults, mind that our brain be scanned knowing the possibility of invasion of privacy? If our answer is no to this question, then we have some thinking to do.

2 This term was generated by Dr. James Giordano.
2.2. Information sharing

If fMRI becomes a commonly used technology, who should have access to the information obtained from fMRI? School systems? In the case that abnormalities having some possible educational implications were discovered during non-clinical use of fMRI, should the school system be involved? Insurance companies? Should the information with regard to the unexpectedly discovered abnormalities be shared with insurance companies? If so, now should the child be considered to have a pre-existing condition (J. Giordano, personal communication, July 2011)? What is the acceptable practice for accessing such information? What are the possible issues with regard to sharing such information with the child? How is this going to affect the perception of the self? (Psychological effects): Known self vs. newly constructed self, based on the results of fMRI. How is this going to affect the perception of others? (Sociological effects): Am I superior to the other kids? Do I deserve better than what I am offered? or “I knew there was something wrong with me, now I have the proof.”

How would information sharing affect the child’s school performance? “The more I know about how my brain works, the more I can adjust my strategies (and/or my environment) to learn” (positive effect). “If I am the brightest, do I really have to work hard anymore?” “I knew there was something wrong with me, I shouldn’t even try anymore!” (Negative effect). There is also a possibility that sharing such information would not affect the child’s school performance (no effect).

2.3. Information security.

In order to make sense of the fMRI data collected by large groups of people, comparison and sharing such data would be necessary. Securing such a database would be pivotal. How is this database going to be secured? What are the possible implications of failing to secure such data? What would be done to avoid or minimize inappropriate access, inapt use/misuse, data modification (by others or the individual himself/herself) and “downstream” effects (e.g.- individual and group socio-legal and economic demonstrations of accessed, misused or manipulated datasets) (Giordano, in press)?

2.4. Use of fMRI for cognitive enhancement in children

Brain mapping in terms of function may lead to the cognitive enhancement argument. If fMRI results show an abnormal or inadequate functioning in certain part of the child’s brain, this information may be utilized to either minimize the abnormality or enhance the cognitive skills. This brings the issue of “the ethics of enhancement.” Julian Savulescu (2009) listed the three main arguments with regard to the ethics of enhancement in humans. The first argument deals with the notion that the decision of not to enhance is wrong. The focal point of this argument is that if enhancement is going to improve the child’s life, failure to provide such enhancement would be unethical. It is like depriving a child from a dietary supplement that would provide a stunning intellectual result. The second argument is that we need to be consistent with regard to different types of enhancement. We use environment to enhance children’s lives. Cognitive/biological enhancements should not be considered any differently because environmental enhancements change our biology as well. If we are okay with the idea to change our biology with environmental
enhancements, then we should be consistent and approach biological enhancement in the same manner. The third argument revolves around the idea that if we were to be open to treatment, we should also be open to enhancements; therefore, enhancements should not be considered any differently than alleviating/treating disease. Preventing a disease or treating a disease leads to a good life, so do the enhancements.

These arguments listed by Savulescu have strong points to consider, yet, it does not mean that there are no possible ethical concerns associated with such enhancements. One of the pivotal questions to be answered is “how far is too far with manipulation of biology or embracement of cognitive enhancements?”

2.5. Policy issues

Policy issues are closely related to justice issues. If fMRI becomes a widely used technology for enhancing children’s cognitive skills or eliminating possible future abnormalities, “who would receive this technology” would become one of the central questions; children who really need this technology to prevent abnormalities or children whose parents can afford such technology to enhance their children’s cognitive skills.

If neurocognitive enhancements become prevalent, it is probable that it will not be rightfully available for all. However, such possible imbalanced access to neurocognitive enhancements should not be used as an excuse to prohibit these technological improvements as it is not the case for the practices performed by the prosperous such as tutoring or cosmetic surgery (Farah et al., 2010).

While addressing the enhancement issue, Michael J. Sandel talks about a worry of generating two categories of human beings: the enhanced and the unenhanced (natural). Sandel (2009) argues that the real issue is not the access issue but the moral issue of enhancement and states that “the fundamental question is not how to ensure equal access to enhancement but whether we should aspire to it in the first place” (p. 892). This question must be clearly answered before any policy making takes place.

As our knowledge about how our brain works progresses, such knowledge will hold potential to have a huge impact on every aspect of our life, including but not limited to education. Policies addressing neuroethics cannot be made without the existence of progressive and integrative neuroethics that generate some benefit vs. risk analysis (Giordano, 2011 as cited in Giordano, in press). That is, neuroethics must develop enough to produce multidisciplinary perspective on benefits vs. risks analysis of using such technology. Developing a framework is a pivotal step with regard to policy making. To do so, implementing workshops and discussions among various disciplines is pivotal. Shared responsibility among regularity agencies and scientists from various backgrounds would provide means for protection and improvement of human life.

3. Is the use of fMRI in education a science fiction or is it already happening?

Neurotechnology is already in use in our daily life including the educational domain. For instance there are educational toys produced by neuroscientists. It seems that with the improvement on the neurotechnologies (i.e., fMRI), it is safe to assume that such technology would not be limited to educational toys. More common
uses of fMRI in the domain of education depend heavily on the questions/issues raised in related literature. We have to answer at least the following questions to put fMRI into perspective: What can fMRI tell us about brain functions in children? What can fMRI not tell us about brain functions in children? What are the benefits and risks involving fMRI? These questions along with several other questions raised in this study may seem to involve an unlikely situation but exercising our judgment on such questions would help us be more prepared for use of fMRI.

4. Conclusion

While novel technologies often provide new prospects that offer potentials for improving people’s lives, technologies also bring novel ethical concerns. It would be premature to dismiss the possible use of fMRI in educational purposes because of the concerns related to the use of such technology. It is obvious that more research is needed to guide the policies otherwise prematurely conducted research can result in unfortunate or harmful outcomes for children due to misguided policy making.3

The issues mentioned above pose a very serious question on the usefulness of fMRI. If we were to utilize fMRI in the education of children, such concerns must be eliminated or at least minimized as much as possible. fMRI is a powerful technology that can be used to improve not only pedagogy but also educational settings. However, the lack of research addressing the issues mentioned above jeopardizes the possible use of such unique technology. Any educational practice based on fMRI (i.e., funneling students into appropriate educational programs, Celone & Stern, 2009) would be at best prematurely done unless such issues are satisfactorily addressed. To do that, a multidisciplinary approach is a necessity.

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