NEUROSCIENCE

9. BRANCHES OF NEUROSCIENCE – PART II

9.1. Neurolaw: Background Information

Neurolaw is an emerging field of interdisciplinary study that explores the effects of discoveries in neuroscience on legal rules and standards. Drawing from neuroscience, philosophy, social psychology, cognitive neuroscience, and criminology, neurolaw practitioners seek to address not only the descriptive and predictive issues of how neuroscience is and will be used in the legal system, but also the normative issues of how neuroscience should and should not be used. The most prominent questions that have emerged from this exploration are as follows: To what extent can a tumor or brain injury alleviate criminal punishment? Can sentencing or rehabilitation regulations be influenced by neuroscience? Who is permitted access to images of a person's brain? Neuroscience is beginning to address these questions in its effort to understand human behavior, and will potentially shape future aspects of legal processes.

New insights into the psychology and cognition of the brain have been made available by functional magnetic resonance imaging (fMRI). These new technologies were a break from the conventional and primitive views of the brain that have been prevalent in the legal system for centuries. Brain imaging has provided a much deeper insight into thought processes, and will have an effect on the law because it contests customary beliefs about mental development. Because the science is still developing and because there is substantial opportunity for misuse, the legal realm recognizes the need to proceed cautiously. Neurolaw proponents are quickly finding means to apply neuroscience to a variety of different contexts. Major areas of current research include applications in the courtroom, how neuroscience can and should be used legally, and how the law is created and applied.

The term neurolaw was first used in practice by the neuroscientist and attorney J. Sherrod Taylor in 1991. Taylor's book, *Neurolaw: Brain and Spinal Cord Injury* was used as a resource for attorneys to properly introduce medical jargon into the courtroom and to further develop the implications of neuroscience on litigation. In addition, Taylor explained the consequences of *Daubert v. Merrell Dow Pharmaceuticals*. This United States Supreme Court case resulted in what is now known as Daubert Standard, which sets rules regarding the use of scientific evidence in the courtroom. Behavioral testing and neuroimaging evidence offer a potentially accurate method of predicting human behavior. This advancement would be beneficial particularly for determining guilty criminal sentences or discerning which criminals deserve to be released on parole or detained in jail due to the possibility of future offenses. Not only could it aid in the process of recidivism, it could also show an indication of the need for personal rehabilitation. In light of this information and its potential applications, the legal system seeks to create a balance between just punishment and penalties based on the ability to predict additional criminal activity.

The tendency of the United States criminal justice system has been to limit the degree to which one can claim innocence based on mental illness. During the middle of the 20th century, many courts through the Durham Rules and the American Law Institute Model Penal Code, among others, had regarded impaired volition as legitimate grounds for the insanity defense. However, when John Hinckley was acquitted due to insanity, a reversal of opinion occurred, which then spurred a narrowing definition of mental illness. Decisions became increasingly based on the M'Naghten Rules, which asserted that unless one was able to prove that a mental illness kept him or her from knowing that the act was wrong, or knowing the disposition of the criminal act, one would not be able to be tried as mentally handicapped. Contemporary research conducted on the prefrontal cortex has criticized this standpoint because it considers impaired volition as a factor. Many courts are now considering "irresistible impulse" as legitimate grounds for mental illness. One of the factors neuroscience has added to the insanity defense is the claim that the brain made someone do it. In these cases, the argument is based on an understanding that decisions are made before the person is able to consciously realize what is happening. More research on control and inhibition mechanisms will allow further modifications to the insanity defense.

9.2. Neurolaw: Technology

Much of neurolaw depends on state-of-the-art medical technology that has been adapted to a new role in the legal system. Among the most prominent technologies and disciplines are functional magnetic resonance imaging (fMRI), positron emission tomography (PET scan), magnetic resonance imaging (MRI), and epigenetics. MRI and fMRI are particularly important because they allow detailed mapping of the human brain, potentially allowing technicians to visualize another person's thoughts. FMRI, a derivative of MRI, allows for oxygen specific mapping to view the most active areas of a brain at a specific moment. Combined with the knowledge of how the brain works in different situations (lying, remembering, etc.), there is the potential to use functional neuroimaging evidence as a modern form of lie detection. Similarly, PET scans use a radioactive tracer injected into the body to analyze brain tissue.

In regard to neuroscience as a form of lie detection, specific regions of the brain have been analyzed in order to uncover patterns of truth telling, deception, and false memory. Notably, an important obstacle to any form of lie detection is when subjects inadvertently recall false memories. This is induced experimentally by presenting subjects a list of semantically related words. While they believe their responses to be true, their recollections are in fact false. This is a normal psychological occurrence, but presents numerous problems to jury attempting to sort out the facts of a case. Indeed, researchers have attempted to distinguish genuine truths from false truths. Subjects are subsequently quizzed on the word list while specific regions of the brain are analyzed for activity. For instance, the dorsolateral prefrontal cortex has been shown to activate when subjects are pretending to know information which they do not know, in contrast to truth telling and false recognition. Alternatively, the right anterior hippocampus activates when a subject presents false recognition in contrast to lying or accurately telling a truth. However, there remain limitations to how much brain imaging can distinguish between the many forms of truths and deceptions. For instance, future research hopes to uncover patterns that differentiate whether someone has genuinely forgotten an experience in contrast to the active choice to withhold information.

9.3. Neuroeducation

Educational neuroscience (also called Mind Brain or Neuroeducation) is an emerging scientific field that brings together researchers in cognitive neuroscience, developmental cognitive neuroscience, educational psychology, educational technology, education theory and other related disciplines to explore the interactions between biological processes and education. Researchers in educational neuroscience investigate the neural mechanisms of reading, numerical cognition, attention and their attendant difficulties including dyslexia, dyscalculia and ADHD as they relate to education. Researchers in this area may link basic findings in cognitive neuroscience with educational technology to help in curriculum implementation for mathematics education and reading education. The aim of educational neuroscience is to generate basic and applied research that will provide a new transdisciplinary account of learning and teaching, which is capable of informing education. A major goal of educational neuroscience is to bridge the gap between the two fields through a direct dialogue between researchers and educators.

The potential of educational neuroscience has received varying degrees of support from both cognitive neuroscientists and educators. Educators are generally enthusiastic about the use of neuroscientific findings in the field of education and feel that these findings would be more likely to influence their teaching methodology than curriculum content. Some researchers take an intermediate view and feel that a direct link from neuroscience to education is a bridge too far, but that a bridging discipline, such as cognitive psychology or educational psychology can provide a neuroscientific basis for educational practice. The prevailing opinion, however, appears to be that the link between education and neuroscience has yet to realize its full potential, and whether through a third research discipline, or through the development of new neuroscience research paradigms and projects, the time is right to apply neuroscientific research findings to education in a practically meaningful way.

The emergence of educational neuroscience has been born out of the need for a new discipline that makes scientific research practically applicable in an educational context. Addressing the broader field of mind, brain and education, researcher Kurt Fischer states that the traditional model will not work. It is not enough for researchers to collect data in schools and make those data and the resulting research papers available to educators, as this method excludes teachers and learners from contributing to the formation of appropriate research methods and questions. Learning in cognitive psychology and neuroscience has focused on how individual humans and other species have evolved to extract useful information from the natural and social worlds around them. By contrast, education, and especially modern formal education, focuses on descriptions and explanations of the world that learners cannot be expected to acquire by themselves. In this way, learning in the scientific sense, and learning in the educational sense can be seen as complementary concepts. This creates a new challenge for cognitive neuroscience to adapt to the real world practical requirements of educational learning. Conversely, neuroscience creates a new challenge for education, because it provides new characterizations of the current state of the learner including brain state, genetic state, and hormonal state that could be relevant to learning and teaching. By providing new measures of the effects of learning and teaching, including brain structure and activity, it is possible to discriminate different types of learning method and attainment. For example, neuroscience research can already distinguish learning by rote from learning through conceptual understanding in mathematics.

9.4. Neuroscience Informing Education

Although an increasing number of researchers are seeking to establish educational neuroscience as a productive field of research, debate still continues with regards to the potential for practical collaboration between the fields of neuroscience and education, and whether neuroscientific research really has anything to offer educators. Daniel Willingham states that whether neuroscience can be informative to educational theory and practice is not debatable it has been. He draws attention to the fact that behavioral research alone was not decisive in determining whether developmental dyslexia was a disorder of primarily visual or phonological origin. Neuroimaging research was able to reveal reduced activation for children with dyslexia in brain regions known to support phonological processing, thus supporting behavioral evidence for the phonological theory of dyslexia.

While John Bruer suggests that the link between neuroscience and education is essentially impossible without a third field of research to link the two, other researchers feel that this view is too pessimistic. While acknowledging that more bridges must be built between basic neuroscience and education, and that so called neuromyths must be deconstructed, Usha Goswami suggests that cognitive developmental neuroscience has already made several discoveries of use to education, and has also led to the discovery of ‘neural markers’ that can be used to assess development. In other words, milestones of neural activity or structure are being established, against which an individual can be compared in order to assess their development.

9.5. Social Neuroscience

In the last 10 years, there has been an explosion of interest in the role of emotional abilities and characteristics in contributing to success in all aspects of life. The concept of Emotional Intelligence (EI) has gained wide recognition. Some have made influential claims that EI is more important than conventional cognitive intelligence, and that it can more easily be enhanced. Systematic research has yet to provide much support for these claims, although EI has been found to be associated with academic success and there is some evidence that it may be of particular importance for groups at-risk of academic failure and social exclusion.

In spite of the weak evidence base, there has been a focus on promoting the social and emotional competence, mental health and psychological well-being of children and young people, particularly in schools as the result of the investment in universal services, prevention and early intervention.

The neural basis of emotional recognition in typically developing children has been investigated, although there is little neuroimaging work on atypically developing children who process emotions differently. Males are commonly overrepresented in these atypically developing populations and a female advantage is commonly reported both on EI measures and on most areas of emotion processing. In processing facial expressions the female advantage appears best explained by an integrated account considering both brain maturation and social interaction. Prefrontal brain damage in children affects social behavior causing insensitivity to social acceptance, approval or rejection. These brain areas process social emotions such as embarrassment, compassion and envy. Moreover, such damage impairs cognitive as well as social decision making in real world contexts supporting the Vygotskian view that social and cultural factors are important in cognitive learning and decision making. This view emphasizes the importance of bringing together neuroscientific and social constructionist perspectives, in this case in examining the influence of emotion on transferable learning.

However, there are currently many gaps in the attempt to bring together developmental science and neuroscience to produce a more complete understanding of the development of awareness and empathy. Educational research relies on pupil's accurate self-report of emotion, which may not be possible for some pupils, (e.g., those with alexithymia, a difficulty in identifying and describing feelings) which is found in 10% of typical adults. Emotional awareness can be measured using neuroimaging methods that show that differing levels of emotional awareness are associated with differential activity in amygdala, anterior insular cortex, and the medial prefrontal cortex. Studies of brain development in childhood and adolescence show that these areas undergo large-scale structural changes. Hence, the degree to which school-age children and young adults are aware of their emotions may vary across this time period, which may have an important impact on classroom behavior and the extent to which certain teaching styles and curriculum approaches might be effective. Neuroimaging work is also beginning to help in the understanding of social conduct disorders in children. For example, callous unemotional traits in children are a particularly difficult problem for teachers to deal with, and represent a particularly serious form of conduct disturbance. Jones et al. showed that children with callous unemotional traits revealed less brain activation in the right amygdala in response to fearful faces, suggesting that the neural correlates of that type of emotional disturbance are present early in development.

Researchers from the Centre for Educational Neuroscience in London have been instrumental in developing a research body that investigates how social cognition develops in the brain. In particular, Sarah-Jayne Blakemore, co-author of *The Learning Brain*, has published influential research on brain development related to social cognition during adolescence. Her research, suggests that activity in brain regions associated with emotional processing undergo significant functional changes during adolescence.