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Neuroscience: The Public Agenda and Misconceptions in Education

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Abstract

The purpose of this paper is twofold. Firstly we wish to examine the extent to which neuroscience as a discipline has become incorporated into the public agenda as a result of increased awareness regarding the care and education of newborns through to the age of about three. This research is relatively recent, and is contrasted with the prevailing wisdom of some fifteen years ago. We then wish to explore the links between education and neuroscience, pointing out where there are regions that are theoretically undernourished. Secondly, we wish to examine some of the neuroscience literature written for educators, illustrating that in many instances such accounts lack in substantive content, and that important neuroscientific concepts are misrepresented. The reasons for this are briefly explored. We also wish to give some consideration to what neuroscientific accounts written for educators should look like. These issues are prefaced as a work in progress to the much broader research aim of exploring notions of learning in educational contexts and in neural systems, ultimately with a view to establishing communication between these two paradigms.

1.0 Introduction

The aim of this paper is to examine the extent to which neuroscience as a discipline has become incorporated into the public agenda and to consider the implications neuroscience has for educational practice. Added to this is the concern that misconceptions exist in the educational literature regarding some important concepts in neuroscience. We canvass these in the hope of setting the record straight.

Concerning the first matter, this presupposes an interest in the subject matter that stems from a relationship between neuroscience and the public interests it is intended to serve. It is a complex and multifaceted relationship, and appears to have emerged from the recognition that a 'quiet crisis', affecting the general status and well being of infants, toddlers and youngsters, has been taking place in the United States of America (Levine & Smith, 2001). The complexity of the issue is underscored by such factors as socio-economic status, availability of appropriate health care and affordable health care cover, nutrition, the presence of a stable and nurturing family environment, and the opportunity for infants or toddlers to form attachments with significant others (Shore, 1997; U.S Dept of Education, 1999). What reads like an account belonging to the archives of the department of social welfare, has only until relatively recently been under-girded by significant evidence from research in neuroscience (Shore, 1997). This research is detailed, charting the development of the brain and nervous system in utero to birth and the years that follow. Necessarily this presages issues of intervention, and from the point of view of the relevant neuroscience, the suggestion is that the safest maxim for early intervention *from birth on* is not too soon (Talay-Ongan, 2000). Classically, the nature-nurture debate has been implicit in this discourse and the relationship between genetic endowment and the interplay of environmental influences has occupied at least part of the discussion in this exciting field of developmental neuroscience. Further to this, the relationship between the significance of (early childhood) education and neuroscience has been continuing to gain prominence within the public sphere, as has been the broader program of pedagogical practice and its relationship to learning and the brain. This relates to the second matter we wish to consider. Here we examine some of the neuroscientific literature written for educators, pointing out that from our perspective, there are three main areas that need to be addressed. These areas deal with substantive content, conceptual misunderstandings and methodological issues respectively. Whilst one may speculate as to the reasons why these issues arise in the first place, and we briefly give consideration to this, it seems fairer to examine examples of such literature in order to see where such shortcomings are placed.

For the time being however, we canvass the neuroscience and public program debate, and in so doing begin with looking at corporate awareness of the neuroscience issue, wherein large measure such interest has been forthcoming from the United States of America.

1.1 Corporate Awareness

The Carnegie Corporation and the Charles A. Dana Foundation

The Carnegie Corporation is a non-profit organization, committed to raising awareness of, and funding where appropriate, projects that are of public significance. Prompted by President George Bush's declaration that the 1990's be hailed as the decade of the brain, members from varied sectors of the community began to show interest in neuroscience, and in particular the implications this has for early years education. In large part, a formal charter for this interest was fueled by the attention raised in the publication of the Carnegie Corporation's report, *Starting Points: Meeting the Needs of Young Children* (Carnegie Corporation, 1994). This report documented the burgeoning literature on young children's emotional, social, physical, intellectual and brain development, emphasizing that how children function from pre-school to adolescence and adulthood, is in large part affected by their experiences before the age of three (Ramsburg, 1997). A general view taken by the corporation is that if current attention about the brain leads to public debate and discussion about the services for young children, that is a healthy sign. At the same time, they noted that caution should taken in shaping programs around research that is still tentative and emerging (Jacobson, 1998). Their involvement with the Clinton administration is also to be underscored, convening on expert panels where such issues as the plasticity of the young brain, as a dynamically changing structure that records its experience in its wiring, were discussed (Society for Neuroscience, 1997). This emerging research picture links quite nicely with the fact that children need opportunities for vigorous, safe physical activity. They need touch, sound and images, and emotional and social contact, along with thought provoking activities. Such activities promote neural activity that becomes integrated within the developing brain. Yet despite parent's best intentions, children were receiving stimulation well short of the optimal level for their age. Such was a finding from the *Starting Points* report, cited at a White

House conference (U.S Dept of Education, 1999) on ‘Early Learning and the Brain.’ Lindsey (1998), in discussing various aspects of the Corporation’s insights into the relationship between the infant and his/her brain development, notes that for centuries parents have understood the newborn's basic need for safety, nourishment, warmth and nurturing. Now, a comprehensive research picture offers insight about human development from birth to age three, cementing the view that parents and other adult caregivers play a vital component in the child’s development. Amongst such research findings, Lindsey (1998) notes the following:

- Brain development that takes place prenatally, and in the first years of life, is more rapid and extensive than previously realized.
- Brain development is much more vulnerable to environmental influence than ever before suspected.
- The influence of early environment on brain development is long lasting.
- The environment affects not only the number of brain cells and the number of connections among them, but also the way these connections are ‘wired’.
- New scientific evidence exists concerning the negative impact of early stress on brain function (pp. 98-99).

The general tenor of these findings are in contradistinction with the fact that only some fifteen years ago neuroscientists thought that by the time a baby was born, the structure of its brain in terms of hard wiring had already been genetically determined (Begley, 1997). But current wisdom places this view as incorrect. Rather, and has already been noted, early childhood experiences shape and determine how the intricate neural circuits of the brain are wired. Therein lies the delicate balance between ‘nature’ and ‘nurture’.

This much and more is taken up by Shore (1997) in her *Rethinking the Brain: New Insights into Early Development*. Funded in part by the Carnegie Corporation and the Charles A. Dana Foundation, Shore places an infant’s neurological development within a modern context. This is prefaced by the fact that there is a very wide gap between scientific research and public knowledge, between what is known and what is done. The criticism is put forward that pivotal institutions within the U.S have not given due consideration to the growing corpus of knowledge on early brain development. It is only when an effort is made to tackle such problems, that the neuroscientist’s findings can be seen to have merit. That is, their understanding about the sequence and timing of brain development can be immensely useful to parents, teachers, health providers, policy makers in diverse fields, and other people responsible for the well-being of children and families (Shore, 1997). Thus there is a central argument that having at least some technical knowledge, i.e., an understanding of neurons, synapses and neuro-chemical transmitters, is going to aid in parental understanding of what general types of processes are likely taking place in their infant’s brain. This of course is short of fully-fledged medical knowledge, but nevertheless adds some sensitivity in creating an informed knowledge base; a base that is to support the delicate yet rigorous business of raising an infant. Augmented with what is already intuitively known about the practices of sound child rearing, we here find in the ideal sense, a nice complement between best practice derived intuitively, and best practice supported by an active research program. The research program as Shore points out, is rapidly becoming multi-disciplinary in nature.

For instance, professionals in education and human services are becoming more receptive to new knowledge about human brain development, and developmental psychologists and anthropologists are turning to neuroscience for insight into the relationship between the workings of the human mind and the evolution of different cultures (Shore, 1997).

This issue is in many senses pivotal, for it addresses how cross- collaborative efforts may be instituted, and with what degree of success such activity is accorded. The Education Commission of the States (ECS, 1996) in conjunction with the Charles A. Dana Foundation, conducted a workshop where workers with expertise in neuroscience and education came together in an effort to bridge the divide between the two disciplines. One of the most central points raised was by that of Professor Patricia Goldman-Rakic of the Yale University School of Medicine. She alluded to the fact that research findings in neuroscience must surely have some implications for how we approach education, and the onus is on educators to tell us what they are (ECS, 1996). This creates a theoretical dilemma, for the simple reason that the language of neuroscience is not easily or readily translated into nicely packaged educational protocols. In a general sense, as a response to this challenge, Professor David Geary of the Department of Psychology at the University of Missouri at Columbia, suggested that the first step in bridging the divide between education and neuroscience is to find a *conceptual framework* that will link neuroscience, psychology and education. The details of this centre on competency and skill acquisition viewed within an evolutionary context, where for instance, compared to others members sitting on the evolutionary tree, human individuals are primed to acquire language skills, but not to learn to read and solve complex arithmetical problems. This is suggestive of the possibility of critical periods for such competencies, and a role for educators to play is to attempt an analysis of whether there are such periods. True, this may be a tall order, but Geary argues it is a step in the right direction if we wish to attain some kind of fruitful cross-disciplinary exploration. He is direct in stating that we need to know what emerges in school and what doesn’t; we need to know what qualities are continuous across human cultures, and which are not; we need to know what works for most or all kids, not the 10% or so who pick up secondary skills without much effort (ECS, 1996). Thus it appears that the relevant neuroscience is necessarily peppered with, perhaps even underpinned by, an essential anthropological component, to reiterate Shore.

Whilst at first blush the preceding discussion may appear somewhat academic in nature, and therefore divorced from public awareness per se, we wish to guard against such an interpretation. Such layers of knowledge as there be may be usefully represented on a continuum, and the public dimension which is of interest to us, may be viewed as an integral part of this. For instance it has been said that our knowledge in the area of neuroscience has doubled in the last ten years. More generally, there has been scientific excitement surrounding research on the brain, with recognition of the significance for the health of the public, given the massive toll of diseases and disorders of the nervous system (Blakemore, 2000). From this sort of background, leaders in neuroscience had been persuaded to prepare a statement of achievable goals for the Decade [of the Brain], and to sign up to the mission of raising public awareness of the importance of neuroscience (Blakemore, 2000). The impetus for this sprang from the efforts of David Mahoney, Chairman of the Board of the Charles A. Dana Foundation, and gave birth to the Dana Alliance for Brain Initiatives. In 1997 this was followed up with the establishment of the European Dana Alliance for the Brain, and organization devoted to informing the public about brain research. As a result of this, each year researchers, clinicians, advocacy groups, funding agencies and so on mount programmes as part of their ‘Brain Awareness Week’ in order to raise public awareness of neuroscience and brain related issues (Blakemore, 2000; Snell, 2000). Clearly then, with the activities of such organizations in the United States and Europe, as well as other like minded organizations dotted around other parts of the globe, we can glean knowledge of the relevant neuroscience and brain related issues as percolating through the fabric or web of public knowledge. In view of the incidence of brain-based pathologies, and the possibilities of treatment with gene therapies, public awareness and indeed public debate is seen as an essential component to the evolving neuroscientific enterprise. Here informed comment is not limited to one of a few specialized groups privy to a rarefied knowledge. No where is this seen to function more at a grass roots level than with neuroscientists ‘brain storming’ with students from local American high schools during one of the Dana Alliances ‘Brain Awareness Weeks’. Held at the National Museum of Health and Medicine, students canvassed with the experts such issues as: The Promise of Neuroscience; Understanding Alcohol – What Science Tells Us; The Science of Drug Abuse – What Do We Know; and from the Deputy Director of the National Institute of Neurological Disorders and Stroke, a session on Know Your Brain. (Medical News Service.com, 2001). Still there were other sessions on how the brain is used, and what in principle constitutes a normal brain. These sorts of activities are seen as crucial, bringing specialized knowledge into the classroom; and in a situation where students belong to a family unit, there is the possibility of discussing the day’s findings with parents. Thus an important goal of the Dana Alliance is being achieved. Knowledge from the specialist groups finds its way into the classroom and minds of (hopefully) interested students, and from there to home where, given the right circumstances, discussion may well follow, and continued interest is shown. If it is a family affair, so much the better, as this brings us closer to the goal of an informed general public and the layers of knowledge that this implies.

In summation then, it seems reasonable to suggest that the neuroscientific enterprise is a heterogeneous entity, stratified into public, private and academic sectors. The dissemination of knowledge, and likewise the distribution of funds, is structured and impelled by an engine whose goal is to achieve a deeper understanding of the systems and processes that under gird the functioning of the human brain. Philanthropic organizations such as the Carnegie Corporation, and the Charles A. Dana Foundation have been largely responsible for providing much of the impetus into neuroscience and the public program debate. Their agenda is necessarily rather broad in its scope, as this covers important developmental sequences in utero, to birth and the years that follow, and indeed much of what has been already intuitively known about sound parenting has now been borne out by relatively recent research in neuroscience. Implicit in this description is the nature-nurture debate, and the fact that each influences the other in a mutually complementary manner. The upshot of this is that from birth to the age of about three there is a crucial developmental period for the care and early-years education of the toddler. Living in a safe and loving environment where attachments can be formed with significant others is an essential part of the toddler’s healthy neurological development. Despite quite remarkable progress in understanding and the implementation of early year programs, significant theoretical issues remain to be resolved. Here the challenge lies principally in forging formal links between education and neuroscience, and at a basic level, finding a suitable working framework within which to address such educational issues as critical periods for skill acquisition and competency. Theoreticians are urged to explore such regions in the hope of contributing to cross-collaborative endeavors. Here for instance the telling comment of Professor Goldman-Rakic that research findings in neuroscience must surely have implications for how we approach education provides a theoretical challenge to workers in the field; one that can be tackled in the years that follow.

From this we move to the section that follows, and consider the links between education and neuroscience that appear to be theoretically undernourished, and in part, diagnose this as arising from educational literature that misrepresents important neuroscientific concepts. Another contributing factor to this, so we suggest, stems from the fact that very little research in Australia appears to have been conducted that explores the relationship between education and neuroscience. As a result the theoretical underpinnings of such a research agenda have not been able to blossom in an area that may not even be classified as being in its infancy. Of course it is difficult to make such a claim with any degree of real certainty. Further to this, the time course of political and economic matters here in Australia appears to lag behind those of the United States; another reason why a paucity in this area of enquiry may exist. Whilst it remains a matter of weighing up the possibilities, the following outline is an attempt to erect a scaffolding, and make some in roads, towards addressing this apparent lack of detail in a potentially quite exciting research agenda.

1.2 Some Neuroscience Literature Written for Educators Appears to Lack Rigor

Here we examine educational literature about neuroscience, and consider three general areas where we argue there is room for improvement. These areas are ‘substantive content’, ‘conceptual misunderstandings’ and ‘methodological issues’ respectively. It is hoped that this brief survey will help to illuminate some theoretical and practical notions that need to be considered when discussing the subject matter of neuroscience.

Substantive Content

We begin with Glenn (2002) who provides a list of some twelve points that teachers should consider for implementation in their classroom, as these, he suggests, arise directly from applying the principles of brain research. One of these is that lessons should be emotionally laden and positive, in order to increase the likelihood of a student retaining the material being taught. This reads more like a principle of motivational psychology than it does a fundamental tenet of neuroscience. Where in his account is mention made of the limbic system (Washington, 2002), thought to be inextricably linked with the emotional state of an individual? And to this, that the limbic cortex is in turn comprised of a number of association areas. Perhaps it could even be argued that the reticular formation also be considered, as arousal necessarily precedes emotional awareness in this description. These details are technical and though the mechanisms of their operation have not been outlined, it speaks at a level of description more formal in character than the one Glenn offers us. Why should this level of description be important for educators? If the claim is being made that neuroscience has implications for the classroom, then knowledge of the association areas and the temporal cortex portion of the limbic region, informs the educator at two levels. The association corticies automatically suggest the possibility of employing cross-modal integration techniques as part of a teaching protocol, whilst the temporal lobe portion of the limbic association cortex is implicated in memory function. The two working in concert will hopefully provide for an instance of learning that was charged with pleasant emotional content that was also memorable. The point being made is that these added layers of knowledge result in a teaching practice that is informed. The practitioner then utilizes techniques that work, or designs new techniques in order to improve on existing ones, and does so with an understanding of the underlying neuroscience. Teaching practice may then be seen as a process of hypothesis design and implementation, constrained by the guiding lights and theoretical perspectives of the various domains and sub-domains of a mature neuroscience. A similar point can be made from a reading of Sousa (1998). He maintains, as do Jennings and Caulfield (2003), that we learn best when we are involved in interesting and challenging situations. Talking about learning is important, and he goes on to say that:

> Talking activates the brain’s frontal lobe, which is necessary for understanding, meaning and memory (Sousa, 1998, p. 24).

The point raised in relation to Glenn (2002), illustrates that no mention has been made of temporal regions of the cortex in the laying down of such memories, or indeed of the role played by the hippocampus in such memory formation. To this, it appears somewhat simplistic to state that such vital attributes as understanding and meaning are compartmentalized to the frontal lobe. It seems more accurate to say that such abilities are distributed throughout various regions of the cortex, and part of this involves frontal regions. We are also left wondering at what neural mechanism is responsible for conveying meaning and understanding to the individual in question. That is to say, to what extent does signal enhancement and reverberation play a role in cementing such things as meaning and understanding? To counter this by saying that such knowledge is not relevant to the classroom situation appears to go against developing an information processing account essential to a dynamical study of cognitive processing by the brain. And indeed we maintain this approach is essential in augmenting and informing teaching practice from the point of view of the relevant neuroscience.

Though Pierson (2002) argues persuasively for the inclusion of physical education as part of an academic program, the account, in some senses appears to gloss over some important details. As is stated:

> In the same way that exercise shapes our muscles, heart, lungs and bones, it strengthens the basal ganglia, cerebellum and corpus callosum – all key areas of the brain (Pierson, 2002, p. 21).

Whilst such comment has a substantial element of truth associated with it, from the point of view of establishing links to the relevant neuroscience, we are left wondering what roles are played by such structures as the basal ganglia, cerebellum and corpus callosum. The fact that the first two of these are intimately involved with the electrical signaling of motoric programs, and the control of muscular movement, has not been mentioned. Nor the fact that mixing lateralized physical activity is going to promote the exchange of information between the hemispheres, *via* the corpus callosum. It seems that if physical educators wish to promote their discipline, and undergird it with a so-called 'brain-based' approach, they ought to delve a little more deeply into the neuroscience that underlies much of what is already understood about the benefits of physical activity.

According to Magnuson (2002) the foundations of brain based education are to be found in the 'Three C's'; Climate, Community and Curriculum. In her account she correctly states that a goal of sound pedagogical practice is to set up a positive emotional environment in the classroom. Most would surely agree that such an approach is to be applauded. So much for the better. Be that as it may, there are three issues to which we draw attention. The first is in her claim that we possess a 'logical side', and that this is in some way involved with goal setting. The confusing thing about this notion is to what extent may we interpret this literally. We have in mind the fact that laterality studies may be in some way relevant to these considerations, yet Magnuson does not appear to explore this link. To this, of course it should be added that the literature on laterality studies is vast, and one should take care in drawing general conclusions. In the absence of such reference however, it is difficult to extract precise meaning of an individual possessing a 'logical side', more so as her treatment is supposed to espouse the virtues of brain-based education. The second issue bears directly on the way the classroom is 'set up', i.e., with a positive emotional environment. As a result of having 'set up' the classroom this way, it should:

> …..help students create those memory pathways (Magnuson, 2002, p. 46).

It is unclear what is meant by the term 'memory pathway', and once again the reader struggles to fill in the details. For us to do this we again refer to the hippocampus, and in this instance consider its circuitry. For instance, such structures as the subiculum, entorhinal cortex, fascia dentata, and the regions CA1 and CA3 are implied. It is questionable whether Magnuson has this in mind, as no mention is made of this, or of hippocampal links to the neo-cortex, nor of the difference between short-term and long-term memory. At a less technical level, and of relevance to building memory cues, Magnuson's account could be suitably augmented by the treatment offered in King-Friedrichs and Browne (2001), as they canvass some of the essential factors in memory encoding.

The third and final issue we wish to raise is found in Magnuson's section on curriculum. She proffers the notion that curriculum should be relevant and meaningful, and that central to this is that:

> Sense and meaning are usually required for new learning to be stored (Magnuson, 2002, p. 46).

Again we are left to ourselves to speculate, as we ask the obvious question; How is it that such new learning may be stored? What sort of models do educators and neuroscientists use when trying to describe such phenomena? Granted that such an area is at the crossroads of vigorous debate, Magnuson appears to make no attempt to address such issues in the interests of further developing our understanding of the relevant neuroscience. What of local and global patterns of resonant electrical activity, distributed over cortical and sub-cortical regions of the brain? What of signal comparison, with either match or mismatch of feedback expectancies? Concepts such as these are embedded within a more fully articulated account of brain function (Grossberg, 1980), and in some respects at least are useful when discussing the neural dynamics of learning. In Magnuson we find gaps and unexplored regions. This is disappointing, and whilst not wishing to appear over critical, it is gaps such as these that lead us to question the underlying motivation for writing such an account in the first place. It appears that the eagerness to embrace a brain-based approach has not been followed up with anything like the rigor one would expect of an educator seeking to establish clear and firm links between h/er discipline, and a subject matter such as neuroscience, that is detailed and complex.

Conceptual Misunderstandings

We begin this section with a consideration of Nunley (2002), who provides an account that seeks to mesh the findings of MEG (magnetoencephalography) studies, with teaching strategies applied in the classroom setting. She reports on the impressive nature of MEG, citing its ability to:

> …..watch the actual processes of brain activity almost neuron by neuron (p. 53).

The question we ask of this, is in what sense would such information be useful? She makes no reference to a Hebbian learning paradigm, where such observations *are* of relevance. This of course misses the point, as she and her colleagues are interested in studying the various regions of the brain that are active when a student is engaged in a process of cognitive task performance. And in order that we may understand how to interpret these findings, we are told that:

> Squiggle lines indicate electrical activity in 122 areas of the cortex as detected by the sensors during the MEG testing (Nunley, 2002, p. 54).

Presumably one is supposed to be able to develop an adequate mental picture of what a squiggle line in neural tissue is, if that does not misread the text. Perhaps the squiggle line is produced by the sensor itself and if so, one naturally asks how such a pattern is produced from the neural tissue that gives rise to it. And to this, presumably we are also to understand that the regions of cortex alluded to are in fact known as Brodmann areas. This of course does not touch on the methodological matter of choice of subjects over an age range of 13 to 19 years. Cortical maturation aside, handedness, issues of lateralization, socio-economic background, gender, race, diet and the like are not mentioned as possible factors of relevance, that could possibly confound the measures being sought. Rather, a 'Learning Style' inventory was employed as the basis for determining which subjects preferred auditory or visual processing. We are told that hundreds of subjects were screened, though those having sustained traumatic brain injury at an early age had to be discounted from the group, as this:

> …..could mean significant plasticity in the brain, thus distorting normal processing (Nunley, 2002, p. 54).

What remains puzzling in this remark is the fact that plasticity, being used as a criterion for exclusion based on traumatic head injury, is in fact a process thought to underlie the dynamics of cognition, throughout the course of a person's life, and this *is* a normal process. It would seem more accurate to say that compensatory mechanisms that utilize neural plasticity, account for some of the differences in the dynamics of cognitive processing in some members of the population. Even if this point were overlooked, are we to understand that such subjects neither process information visually or by auditory means? A more likely explanation would tend to suggest that certain tasks had been either completely or partially lateralized in a manner different had there been no head injury. It remains an open question as to whether the reader is expected to fill in such gaps. And so this and one final matter is put to Nunley (2002). It was claimed that in many cases there was no correlation between a student's preference for auditory or visual processing from the inventory results, compared with MEG results. It was noted that nearly half of the student's brains showed a sensory preference; some stronger than others. Asides from attempting to explain the difference between the MEG and inventory results that Nunley alludes to in her account, we are left wondering how the *strength* of this sensory preference was, or is, to be measured. Perhaps there were variations in the color intensity of the pixels from the computer-generated image of the MEG, if there be such a thing. Whatever the case, one wonders at the utility of having the reader speculate on such matters, when it is an educator, i.e., Nunley who is arguing that we embrace the findings of neuroscience. Surely in attempting to sustain such an argument, one would be expected to embrace the language of the profession we seek to understand.

Relevant to embracing the language of a profession we seek to understand, it is inevitable that we be disappointed in Baylor (2000). He is keen to point out that with the ever increasing pace of technology and the information age, networking amongst professional groups now appears to be the norm, rather than the exception. And in drawing a parallel between networking in the sense of neuroscience, to that of professional networking, he states that information may be transmitted as the result of the communicating units sending electrical synapses to one another. Despite the fact that such a description was intended as a metaphor, it seriously calls into question the understanding of such a fundamental concept. The synapse is defined as the gap that arises in relation to the pre-synaptic terminal and the post-synaptic membrane. It is a physical structure, distinct from the action potential of the pre-synaptic neuron, and the excitatory and inhibitory post-synaptic potentials of the post-synaptic neuron. It is in this electrical and chemical activity that we have orchestrated neural activity. The synapse is a structural and functional unit, and is certainly not 'transmitted' in the manner suggested by Baylor.

There are still more conceptual gaps to be found in Rushton, Eitelgeorge and Zickafoose (2003). Here they discuss Brian Cambourne's 'Conditions of Learning Theory', and attempt to link it with the principles of brain research. In dealing with one of the conditions of learning known as immersion, they comment on the relevant neuroscientific principles in the following manner:

> Research suggests that with each new learning experience, the cells of the dendrites branch out to connect with other dendrites, and with repeated exposure to a learning task, the myelin sheath that surrounds the axon portion of the dendrites thickens; hence, the greater the difficulty or complexity of the learning taking place, the more the myelin sheath grows. The belief is that the thicker the myelin sheath the more encapsulated the learning is and the faster the memory response time is in recalling information (Rushton, Eitelgeorge & Zickafoose, 2003, p. 13).

Part of the problem with the above approach centres on having an adequate understanding of what a neuron is, as this is the fundamental unit of information transfer. Dendritic branches or the dendrites themselves are not individual cells, as the above comments indicate. Rather characteristic dendritic arborization belongs to an individual neuron. It is the neuron that is a cell in and of itself. Dendrites are characterized by having the synaptic terminals or boutons juxtaposed to dendritic spines. There is no actual contact, rather a very small gap exists between the bouton of the pre-synaptic neuron and the dendrite of the post-synaptic neuron. This gap, so described is what constitutes a synapse as we have discussed previously. Further to this, there is strictly speaking no axon portion to the dendrites. This is a terminological point, for although there is a sense of continuity characterizing the overall structure of the neuron, dendrtites are characteristically anatomically different from the myelinated axon that emerges from the cell body of the neuron. Further to this, even if the myelin sheath thickens with continued neural activity, it is difficult to understand what is meant by learning being encapsulated. Learning is a phenomena, that in neuroscientific terms is probably at least partly described in terms of electrochemical activity taking place within a given spatio-temporal domain, i.e., that patterns and correlations of such activity vary from one learning experience to another. Recall our description of the local and global patterns of resonant activity within cortical and sub-cortical regions of the brain. Encapsulation as a metaphor does not appear to find a place within such a description. The reason? Myelination per se is a property of a neuron, and has a static qualitiy about it. Learning in the neuroscientific sense, on the other hand, is an active and dynamic process, dealing with the activities of networks of neurons, within particular regions of, and between particular regions of, the brain. Stated another way, the fact that nerve fibres are encapsulated with myelin is a structural property of the neuron, distinct from the activities of neurons that characterize the learning process.

There appear to be other misconceptions as Rushton, Eitelgeorge and Zickafoose (2003) discuss linking brain principles with Cambourne's 'response' condition of learning. We note:

> Although nerve endings do not actually touch, the electrical impulse, firing of one nerve to another (called synapses) transfers various chemicals and thus creates meaning (Rushton, Eitelgeorge & Zickafoose, 2003, p. 20).

From our previous discussion it should be plain that the synapse is defined as a structural arrangement, as opposed to a description of the electrical activity of the neuron or neurons in question. Added to this, is the rather perplexing notion of how Rushton et al., propose to extract meaning from an instance of chemical transfer. That is to say, in what sense can meaning be extracted from the release of neurotransmitters? How are we expected to bridge the divide between electro-chemical activity on the one hand, and the emergence of meaningful behavior and learning on the other? Rushton et al., do not so much gloss over the issue, as expect the reader to accept that there is no theoretical structure that can be suitably interfaced between the two positions. We question the validity of this on theoretical grounds, arguing that it should be possible to extract meaningful symbolic accounts of learning and behaviour from non-symbolic architectures, provided that such architectures are interpreted in a logically coherent manner.

In her discussion of how educators learn, Nevills (2003) is keen to incorporate findings from neuroscience to substantiate her pedagogical claims. What we find here, is we suspect a mixed bag peppered with partial truths, and potentially misleading concepts. In describing an adult learning sequence, reference is made to linking previous learning or experience, and what is put forward as an underlying neural prinicple is that:

> The brain searches the cortex for neural networks with common terminology, patterns, sequences or categories (Nevills, 2003, p. 22).

To begin with, the entire cerebral cortex is a rich, thick and dense neural network, so presumably the search referred to takes place within a sub-set of the larger network in question. The entire brain is characterized by electro-chemical activity, and on that basis, it is difficult to understand what is meant by common terminology, patterns, sequences or categories. Perhaps patterns refer to patterns of electro-chemical activity, though if so, we ask why such an important point was not made explicit. Rather, such descriptors appear more metaphorical in nature, rather than making any substantive claims about what neural processes are thought to be involved. Common terminology, as a linguistic device, in much the same way as categories, may have use in the development of cognitive models, but strictly speaking these do not belong to the discourse of neuroscientific theorizing. Furthermore, Nevills goes on to claim that the hippocampus is involved as individuals determine whether a given topic or activity is worthy of attention. It is our understanding that the reticular formation is essential for keeping the cerebrum conscious and alert, and based on that, it may be that the above comment is in some sense an oversimplification. It seems more accurate to say that crude or primitive attentional mechanisms are likely to stem from the reticular formation, and that at a higher level of processing this mechanism is suitably augmented by the hippocampus proper. As indeed hippocampal function as part of the limbic region has been noted previously. More so, the hippocampus is implicated in the selection, classification and storing of experiences into memory (Greenleaf, 2003), and the formation of spatial relations. Other issues relate to how we conceptualize neural activity when new material is being learnt. We are led to understand that adults, like children, are constantly developing ‘superhighways’ of neurons among different areas of the cerebral cortex, and that once the connection has been made to past information, the new ‘neural highway’ is created. How is this possible? Does creating a ‘neural superhighway’ mean the creation of new neurons, or does it relate to the use of neurons that had been previously inactive? The two notions are vastly different from one another; one substantially incorrect, and the other correct. And where is mention made of the spatio-temporal nature of such neural activity, distributed throughout various network ensembles? This is an important point. It is how the electrical (neural) activities from brain region to brain region correlate with one another, that allows us to develop a concept of learning and to understand the emergence of new behavior. It is difficult to extract precise meaning from the sort of metaphorical descriptions Nevills (2003) has on offer, and as such a reader, lay or otherwise, may draw incorrect conclusions.

Much is also left lacking in Haar (2003), as the reader struggles to link certain aspects of brain-based research, with curriculum and policy change in a small American high school. What is mentioned concerning brain-based research falls under the rubric of Integrated Thematic Instruction (ITI), where amongst other things we are told that:

> We have at least seven intelligences….. Each of the intelligences functions from a different part of the brain (Haar, 2003, p. 52).

Notwithstanding the fact that intelligence, like learning, is a complex and heterogeneous phenomenon, we wonder at the likelihood of it being partitioned in the manner described, even if the intention is to label these as ‘Gardener’s seven intelligences’. For if so, what role is then played by the lower and higher regions of cortex? Our current knowledge of brain structure and function tends to indicate that particular complex cognitive domains are inherently distributed, and no singular locus necessarily applies. Indeed, as captured by Slavkin (2003), the brain is thought of as a complex, interdependent ecosystem that allows for singular functions to be organized and performed by multiple areas. Be that as it may, care needs to be taken lest we generalize in the face of counterfactual instances. The ‘one intelligence per one region of the brain’ is likely applicable here, and appears reminiscent of the logic employed by the phrenologists, prior to the pioneering work of Santiago Ramon y Cajal (Kandel, Schwartz & Jessel, 1991; Purves & Lichtman, 1985). Not withstanding such comments, whatever partitioning does appear legitimate is illustrated, for instance, by the well-known Brodmann areas; and these number well in excess of the seven principal regions alluded to, though not labeled, in the above account.

Methodological Issues

We begin this brief preview section by drawing attention to Kussrow (2001). His agenda deals with educational leadership, and his interest is in the implementation of brain-based leadership design. Central to this is ensuring that all things being equal, an environment for learning should consist of a stimulating environment and one that allows for the affirmation of social bonding. To this, environments should be safe and sensory rich, allowing for the exchange of information and for opportunities where positive feedback is encouraged. This much is uncontentious, and reads like familiar psychology. There are however a couple of points we wish to raise. In suggesting that stimulating and enriched environments are crucial to efficacious learning, Kussrow alludes to the oft-cited claim that rats were shown to evince structural modifications in their dendritic fields, as a result of being exposed to enriching stimuli. He then generalizes, and with this generalization juxtaposes the notion of dendritic branch proliferation and increased number of spines and larger terminals, with the notion of change in humans. A questionable methodological ploy, so we suggest. Questionable because one may be led to think that dendritic proliferation may occur in humans as the result of being exposed to an enriched and stimulating environment. This is a highly contentious point, and one that is being actively debated in the literature. To this, the claim that high brain connectivity is associated with a critical period for learning, far from being a neuroscientific finding about which educators can be confident, is at best neuroscientific speculation (Bruer, 1999). Thus prudence in discussing these matters should prevail, and the reader should not be led to making hasty decisions. Furthermore, and as equally significant, the rat does not occupy the same position on the phylogenetic tree as the *homosapien*. Thus, care needs to be taken when evaluating claims from one species to another, lest overgeneralization results in the making of claims that are unwarranted (Byrnes & Fox, 1998; Hannon, 2003). We also note that Kussrow (2001) states that the brain uses at least 21 different senses as it is processing or absorbing input, while building its own perceptual maps. We are aware of sight, touch, olfaction, taste and hearing, and question what the remaining 16 senses could possibly be.

In a general sense then, the methodological point as raised by Puckett, Marshall & Davis (1999), is clear:

> We need to keep in mind that the growing body of brain development research represents a multifaceted work in progress, and, as such, is not a singular nor completed study from which easy or simplistic conclusions can be drawn. There is much yet to be learned regarding interpretation and application of brain research (p. 8).

Others such as Bruer (1998, 1999) also maintain that claims in support of a 'brain-based' approach to education should be handled with caution and due consideration. For instance, the part versus whole scenario in cognitive processing, and what this says about hemispheric lateralization, in particular, should not be reduced to simple formulaic approaches. Lateralization is a complex issue (Bruer, 1999), and where amongst other things, the notion of inter-hemispheric transfer of information via an intact corpus callosum need be considered. Furthermore Bruer (1998) draws a distinction between a complex and an enriched environment, and what this may say about synaptic densities, the establishment of neural connections, the learning process and so on. He expresses concern that the meaning of such terms are applied differently within neuroscientific and educational contexts, and where from the educational perspective one cannot double for the other. Indeed as he states (Bruer, 1998):

> As far as neuroscience goes, all these activities and environments are equally complex – and neuroscience says nothing about which are more or less enriched than others. In assessing claims about environments and the brain, we should be aware of how easy it is to slide from describing complexity to prescribing enrichment (p. 18).

Such evaluative concerns appear to be well founded, and we concur with Bruer on the need to make consistent use of a given vocabulary, or collection of vocabularies. In some senses though, we part company at his suggestion that neuroscience, in its current state of knowledge, has little to offer education practice or policy. Part of the reason for our maintaining this position, is that his account does little to illuminate the reader on the necessarily more rigorous, and theoretically laden, brain dynamical view of information processing within the brain. As a consequence, it seems that an essential part of the puzzle is missing. If neuroscientists are informed, as indeed some or many are, about information processing within biological neural networks, then the quest for translation from one paradigm to inform the other should be a theoretically justifiable pursuit. Indeed, it is from this perspective that one may be better able to understand why one student learns the first twenty elements of the periodic table, by writing a song about them, whilst another prefers drawing articles composed of each of these. This automatically requires a certain flexibility in the practice of teaching, whilst at the same time informing pedagogues, in terms of a brain dynamical theoretic perspective, why some approaches work in some cases, and others do not. And why in that true and very special sense, we must make some effort to tailor our educational approach on an individual basis. Some would undoubtedly disagree with the position adopted here; that is, that a brain dynamical view of information processing is informative for pedagogy in general. The reasons for this, perhaps not always clear, often fall back on the oft-cited claim that one need not know how the engine of a car works, in order to be able to drive a car. And so, by analogy, one need not delve into the realms of brain function in order to be able to teach effectively and efficaciously. Such an argument is, so we contend, vacuous. What happens when a particular teaching method works for one group, or one student, but not for another group, or another student? To not worry about the fact that some students may not learn, is clearly professionally remiss, especially if methods are not employed in order to try and enhance the learning process. Trial and error methods may be employed, and with varying degrees of success. Our contention is simply that an information processing account of cognition, within the context of learning a particular subject matter, is going to augment understanding when trying to devise an appropriate learning strategy. Knowing where and when information is processed, and/or where and when it is not, may allow the informed educator to devise teaching methodologies that utilize cortical or sub-cortical regions that would otherwise be neglected, and that may, as a result of the intervention, produce a successful learning outcome. These ‘before’ and ‘after’ scenarios could for instance be monitored by such techniques as EEG (electroencephalography), PET (positron emission tomography) and fMRI (functional magnetic resonance imaging). The teacher is then engaged in the business of practical neuroscience, as we come to see a meshing of theory with practice.

1.3 Conclusion

The public policy issues associated with neuroscience and the programs debate can be viewed in the context of the 1990’s being hailed as the ‘Decade of the Brain’. This is an American initiative, and concomitant with this, there appears to have had been a carry over effect into the literature written about neuroscience by educators. It is a matter of speculation as to why such literature is lacking in academic rigor, but one suggestion certainly hinges on the so-called ‘band wagon’ approach. In their eagerness to incorporate brain-based findings into their writing, and in their wish to discuss the educational import of such an approach, authors have peppered their texts with misconceptions. Neuroscience is a detailed and complex subject, and in order to do it justice, patience is required in attempting to comprehend some of the concepts that form part of this field of enquiry. Once some degree of comprehension prevails, it should then become possible to convey the meaning of such concepts as there may be in as clear and as accurate manner as possible. For this reason we suggest that educational writing about neuroscience should conform to the established cannons of research practice, as is true of many other disciplines from quantum physics to sociology. When this type of methodological standard has been achieved, the public issues and programs debate can be revisited, with an emphasis on enriching public layers of knowledge, so that the polemic becomes informed and accurate. If such a goal is achievable the prospects for an expanded research agenda become all the more realistic. In an academic context at least we would consider a focus on learning within education and neuroscience, with a view to establishing communication between these two paradigms of thought, and regard this as a fundamental stepping stone to developing a synthesis wherein education and neuroscience reside together comfortably. It is a goal set in the ideal limit, and it is a matter of commitment and hard work in order to see that we get there.

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References

Baylor, S. C. (2000). Brain Research and Technology Education. The Technology Teacher, 59: 7, 6-11.

Begley, S. (1997). How to build a baby’s brain. Newsweek, 28-30.

Blakemore, C. (2000). Achievements and challenges of the Decade of the Brain. EuroBrain, 2: 1, 1-4.
www.edab.net/EuroBRAIN%204%20Anglais.pdf (2.4.04)

Bruer, J. T. (1998). Brain Science, Brain Fiction. Educational Leadership. 56: 3, 14-18.

Bruer, J. T. (1999). In Search of…Brain-Based Education. Phi Delta Kappan, 80: 9, 648-656.

Byrnes, J. P., & Fox, N. A. (1998). The Educational Relevance of Research in Cognitive Neuroscience. Educational Psychology Review, 10: 3, 297-342.

Carnegie Corporation. (1994). Starting Points: Meeting the Needs of Our Youngest Children. New York: Carnegie Corporation.

Education Commission of the States. (1996). Bridging the Gap Between Neuroscience and Education. Denver: ECS.

Glenn, R. E. (2002). Using Brain Research in Your Classroom. The Education Digest, 67: 7, 27-30.

Greenleaf, R. K. (2003). Motion and Emotion in Student Learning. The Education Digest, 69: 1, 37-42.

Grossberg, S. (1980). How does a brain build a cognitive code? Psychological Review, 87, 1-51.

Haar, J. M. (2003). Putting Theory into Practice. Principal Leadership, 3: 9, 51-55.

Hannon, P. (2003). Developmental Neuroscience: Implications for Early Childhood Intervention and Education. Current Paediatrics, 13, 58-63.

Jacobson, L. (1998). Education Policy Makers Embrace Brain Findings. http://www.edweek.org/ew/vol-17/30ecs.h17 (30.3.04)

Jennings, W., & Caulfield, J. (2003). Inciting Learning in Action. Principal Leadership, 3: 9, 45-49.

Kandel, E. R., Schwartz, J. H., & Jessel, T. M. (1991). Principles of Neural Science. New York: Elsevier.

King-Friedrichs, J., & Browne, D. (2001). Learning to Remember. The Science Teacher, 68: 8, 44-46.

Levine, M. H., & Smith, S. V. (2001). Starting Points: State and Community Partnerships for Young Children. www.futureofchildren.org

Lindsey, G. (1998). Brain research and implications for early childhood education. Childhood Education, 75: 2, 97-103.

Magnuson, J. (2002). Middle School Family and Consumer Sciences: Brain- Based Education from Theory to Practice. Journal of Family and Consumer Sciences, 94: 1, 45-47.

Medical News Service.com. (2001). Students Brainstorm with Neuroscientists Brain Awareness Week Programs to be held March 14-15. http://www.medicalnewsservice.com/ARCHIVE/MNS236.cfm (2.4.04)

Nevills, P. (2003). Cruising the Cerebral Superhighway. Journal of Staff Development, 24: 1, 20-23.

Nunley, K. F. (2002). Active Research Leads to Active Classrooms. Principal Leadership, 2: 7, 53-56.

Pierson, K. (2002). Exercise Your Mind: The Importance of Daily Physical Activity in our Schools. Strategies, 16: 2, 21-22.

Puckett, M., Marshall, C. S., & Davis, R. (1999). Examining the Emergence of Brain Development Research: The Promises and the Perils. Childhood Education, 76: 1, 8-12.

Purves, D., & Lichtman, J. W. (1985). Principles of Neural Development. Massachusetts: Sinauer Associates Inc.

Ramsburg, D. (1997). Brain Development in Young Children: The Early Years ARE Learning Years. http://www.nldontheweb.org/ramsburg.htm (30.3.04)

Rushton, S. P., Eitelgeorge, J., & Zickafoose, R. (2003). Connecting Brian Cambourne's Conditions of Learning Theory to Brain/Mind Principles: Implications for Early Childhood Educators. Early Childhood Education Journal, 31: 1, 11-21.

Shore, R. (1997). Rethinking the Brain: New Insights into Early Development. New York: Families and Work Institute.

Slavkin, M. (2003). Engaging the Heart, Hand and Brain. Principal Leadership, 3: 9, 20-25.

Snell, E. (2000). Brains in Brighton. EuroBrain, 2: 1, 5-6. www.edab.net/EuroBRAIN%204%20Anglais.pdf (2.4.04)

Society for Neuroscience (1997). White House Conference Melds Neuroscience and Public Policy. http://web.sfn.org/NL/1997/July-August/white_house.html (30.3.04)

Sousa, D. A. (1998). Brain Research Can Help Principals Reform Secondary Schools. National Association of Secondary School Principals Bulletin, 82: 598, 21-28.

Talay-Ongan, A. (2000). Neuroscience and early childhood: A necessary partnership. Australian Journal of Early Childhood, 25: 2, 28-33.

U. S Department of Education. (1999). 'How Are the Children?' Report on Early Childhood Development and Learning. http://www.ed.gov/How_Children/title.html (27.3.04)

Washington, V. (2002). From Where I Sit: Why Early Childhood Education Matters Now More Than Ever. Scholastic Early Childhood Today, 17: 3, 5.