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Wilderness immersion tuning: education with evolution & neuroscience in mind

Mise au point sur l'immersion dans la nature à l'état sauvage: l'éducation en tenant compte de l'évolution et de la neuroscience

La puesta a punto a través de la inmersión en la naturaleza salvaje: la educación que tiene en cuenta la evolución y la neurociencia

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ABSTRACT

These combined two papers make the case that certain kinds of learning in relatively less human-directed environments, which we call wilderness immersion tuning, not only make good evolutionary and neuroscience sense, but are needed for the optimal growth and learning of young people. The paper is presented in two parts. Part One makes a neuroscience-based case for learning in certain ways in wild spaces. It considers the philosophical idea of humans as embodied learners. It provides a connection between recent neuroscience discoveries and empirical studies highlighting the effectiveness of learning in nature. Part Two extends these neuroscience discoveries and particularly explores psycho-social maturation through learning in less human-controlled places. It calls for learning in wild places for early adolescent students. While the two parts are separated in order to meet editorial guidelines, they are necessarily intertwined and ought to be read as parts of a whole.

Keywords: education, wilderness, experiential learning**,** neuroscience, evolution, wilderness immersion tuning.

RESUME

Ces deux articles combinés présentent des arguments en faveur de certaines sortes d'apprentissage dans des environnements relativement moins touchés par les humains, ce que nous appelons mise au point par l'immersion dans la nature sauvage. D'après les auteurs, ces sortes d'apprentissages font non seulement du bon sens évolutionnaire et

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neuroscientifique, mais sont nécessaires pour la croissance et l'apprentissage des jeunes. Le papier contient deux parties. La première se base sur la neuroscience pour préconiser l'apprentissage dans des espaces sauvages. Elle considère les humains du point de vue philosophique comme des apprenants incarnés. Elle fournit une connexion entre les découvertes récentes de la neuroscience et les études empiriques qui soulignent l'efficacité de l'apprentissage en nature. La seconde partie traite de ces découvertes de la neuroscience et explore surtout la maturation psychosociale par l'apprentissage dans des contextes moins contrôlés par les humains. Elle recommande fortement l'apprentissage dans ces contextes pour les jeunes adolescents. Ces deux parties sont séparées pour répondre aux exigences éditoriales; elles sont nécessairement entrelacées et devraient être lues comme parties d'un tout.

Mots-clés: Environnements dirigés par les humains, la mise au point par l'immersion dans la nature sauvage, la neuroscience, l'apprentissage expérientiel.

RESÚMEN

Estos dos trabajos combinados analizan el caso de ciertos tipos de aprendizaje en entornos menos dirigidos humanamente, los cuales denominamos la puesta apunto de la inmersión sin lo natural y lo salvaje, que no sólo encuentran sentido en la evolución y la neurociencia sino que además son necesarios para una crecimiento óptimo y el aprendizaje de la gente joven. El artículo es presentado en dos partes. La primera pare toma el caso de la neurociencia enfocada al aprendizaje en ciertas formas dentro de espacios naturales. Se considera la idea filosófica de los seres humanos como cuerpo del sujeto que aprende. Se ofrece una conexión entre los recientes descubrimientos de la neurociencia y los estudios empíricos destacando la eficiencia del aprendizaje en la naturaleza. La segunda parte ahonda en estos descubrimientos neurocientíficos y explora especialmente la maduración psicosocial a través del aprendizaje en lugares menos controlados por lo humano. Se desarrolla un posicionamiento a favor del aprendizaje en espacios naturales y salvajes para estudiantes en la temprana adolescencia. Aunque las dos partes están separadas con el fin de cumplir las normas editoriales, ambas están necesariamente interrelacionadas y debes ser leídas como partes de un todo.

Palabras clave: ambientes humanos dirigidos, puesta a punto en la inmersión en la naturaleza salvaje, neurociencia, aprendizaje experiencial.

> But the old Lakota was wise. He knew that a man's heart, away from nature, becomes hard; he knew that lack of respect for growing, living things soon led to lack of respect for humans, too. So he kept his children close to nature's softening influence.

- Ota K'Te (Luther Standing Bear)

We often forget that we are Nature. Nature is not something separate from us.
So when we say we have lost our connection to nature, we have lost our
connection to ourselves.
- Andy Goldsworthy

Tuning; tuned: To put into proper pitch…To adopt or adjust, especially in order to
bring into harmony… To adjust so as to make it resonant with a given
input signal… To adjust for maximum usability or performance.
- The Free Dictionary

Introduction to parts one and two of wilderness immersion tuning

In Part One, we consider the broader implications of the close partnership between the brain's neurons and glial cells. We review the function of neurovascular coupling and the brain's fast/slow information processing capability, and we suggest that these processes reveal a brain/body/environment/mind *continuum of connectivity*. In this context, we reference the theory of embodied perception and discuss implications to learning and teaching. We move from this to extended cognition and the dynamic process we term w*ilderness immersion tuning*. We seek to understand the *wilderness effect* and consider possible reasons for empirical research outcomes that favour learning in wilder places.

In Part Two, we will explore different ways of interpreting wilderness immersion, including as a rebalancing of left and right cerebral hemispheric functioning. We discuss how humans are naturally mobile and experiential learners by biological design and how *journey pattern learning* – especially in and through wilderness environments – functions to effectively advance brain development and self-awareness. We use the lenses of chaos and complexity theories to better understand the typically positive maturational effect of small group, experiential, adventure learning, and we advocate for well structured and wisely led wilderness trips to foster greater social/emotional intelligence and adaptively helpful character traits – especially resiliency and self-control. We conclude by recommending the introduction of a wilderness immersion program in Middle School during the Grade 7 Spring semester for girls and in the Grade 8 Fall semester for boys – or for equivalent early adolescent ages in other-than-Canadian contexts.

NB: We are adopting an operational definition of wilderness or wilder places as those that are under relatively less human control, and we acknowledge a diversity of views on this matter. Also, we gratefully acknowledge the legacy of wilderness environmental education. We know from experience that wilderness educators have come to teach the way they do because experiential learning in wild places has proven effective and is inherently meaningful. For those wilderness educators and others who journey from a deeply felt spiritual connection to the more-than-human world, please consider this paper a different trailhead to the rich experience of being, learning, and teaching in the wild. With it, we hope to reach others who have not come to this understanding through their own practice. Though from different starting points, all journeys begin with a first step.

Introduction to part one

Early childhood (0 to 3 years) and the late pre-adolescent/early adolescent years (8–13 for girls, 10–15 for boys) are both periods of noticeably accelerated physical growth and significant structural/functional brain maturation, as well as important milestone stages in psychosocial development – particularly in the capacity to function separately from primary caregivers while still maintaining healthy attachment.

Insights from neuroscience, evolutionary biology, educational psychology, and applied teaching/parenting practice have focused attention on and investment in early childhood education, but there has been much less pedagogical accommodation for the significant – and somewhat similar – neurobiological and psychological transformation during the adolescent growth surge. This is not only a missed educational opportunity: we suggest it also unnecessarily extends a vulnerable period of youth maturation by not formally integrating into education a program of high-challenge/smart risk experiential learning that is evolution aligned and developmentally timely.

Adolescents are strongly motivated to seek novel sensations, pursue emotionally meaningful experiences, and expand peer group social connections. This inclination towards exploration, discovery, and connection is further amplified during the period of rapid physical growth known as the adolescent growth surge (or spurt).

The adolescent physical growth surge also corresponds with a sensitive period of brain re-organization (Giedd et al., 1999) that incorporates structural, functional, and psychological change. The temporal overlap between accelerated physical body change, significant functional and structural brain transformation, and socio-emotional learning receptivity is not coincidental but closely linked for developmental reasons (Giedd, 2015). As a result, there is a special learning and teaching opportunity during the adolescent growth surge period that can enhance adolescent cognitive functioning and accelerate the development of social and emotional intelligence.

Scientific knowledge of the brain has significantly advanced over the past three decades as a result of research using sophisticated brain imaging technology and experimental innovation. For example, neuroscientists now have a better understanding of the complex processes involved in the tightly coordinated functioning of the brain's neurons and glial cells. The discovery of a direct physical connection – and two-way communication – between a type of glial cell known as a protoplasmic astrocyte and the microscopic blood vessels in the brain that supply nutrients and remove waste has advanced appreciation for the interconnections between the brain, the rest of the body, and the environment beyond the skin. This expansive interconnectedness, and a growing body of research corroborating the multiple benefits of being and learning in natural environments (Kings College London, 2011; Linney & Foster, 2007; Mcmahan & Estes, 2015; Sandifer, Sutton-Grier, & Ward, 2015), challenges us to explore the implications of this research for enhancing public education and optimizing adolescent maturation. However, before we can directly consider these questions, we need to review brain function in light of new research. In Part One of this two-part paper, we review the neuroscience that supports learning in relatively wild places.

A cellular partnership

For most of its evolutionary past, the mammalian/human brain evolved through an embedded and interactive dance with wild nature. As a result, there is a resonating complexity, creativity, and animate-ness between the brain and wilder places, which provide a special opportunity for learning. We explore this in more detail in sections at the end of Part One, and in Part Two. But we begin by considering first the brain's own complexity. We look at how an ongoing dance between its living structure and the world that contains it is a reciprocally shaping process.

The brain of *homo sapiens* contains an estimated 86 billion neuron cells and an approximately equal number of glial cells (Herculano-Houzel, 2015), which, during the first three years of human life, create an extraordinary 100 trillion or more synaptic connections. Each day the human brain filters and processes vast amounts of information received from sensory receptors throughout the body, providing us with the ability to see, hear, taste, touch, smell, move, and much more.

During the last trimester of fetal development (Buss, Entringer, Swanson, & Wadwa, 2012), and for the first year and a half of infancy, the brain exhibits a vast over-production of gray matter (glial cells, neuronal cells, neuropil, synapses, and capillary blood vessels). The over-production of gray matter creates an abundance of connections, which are then extensively trimmed down by a process called "synaptic pruning" until the age of sexual maturation (Huttenlocher, 1979; Iglesias, Eriksson, Grize, Tomassini, & Villa, 2005). Through synaptic pruning, connections between frequently used brain cells are strengthened, whereas those that are seldom activated are discontinued. The benefit of "synaptogenesis," which refers to the process of creating functioning synapses between neurons, is that it shapes the brain to operate more effectively as well as efficiently (Chechik, Meilijson, & Ruppin, 1998) – a transformation adaptively very important given the baseline high energy consumption of the human brain in combination with the additional energetic demands of a suddenly rapidly growing adolescent body.

The misconception of the brain as largely fixed and hard-wired by genetic inheritance has now been replaced by a deeper understanding of the brain's "neuroplasticity" – meaning that it remains partially malleable or "plastic" past childhood and well into adulthood, and is therefore capable of reorganizing its neuronal networks in response to new experiences and training (Hebb, 1949; James, 1890; Konorski, 1948). Recognition of the brain's prolonged plasticity has not only altered the treatment of brain injuries, it has profound implications for youth who may believe that their academic capabilities and potential are unchangeable, when in fact the opposite is true: brain performance capability can be further enhanced.

Historically, the neuron has been the brain cell most studied in the quest to understand the brain. In part, this was because neuron cells are electrically excitable, permitting easier detection with the existing technology. However, in the last few decades, there has been a sea change in appreciation of the multiple and essential roles of the "bush-like" glial cells in brain functioning. In his book, *The Other Brain*, neuroscientist Dr. R. Douglas Fields aptly conveys the new respect for the pivotal role of glial cells in the brain with this description:

> Glia dazzle us with their multitude of communication channels. Neurons are fastidious; glia are promiscuous. . . . Neurons form synapses only with the appropriate partner neurons, but glia communicate with one another and with neurons. . . . Glia are engaged in a global communication network that literally coordinates all types of information in the brain: glial, hormonal, immunological, vascular, and neuronal. . . ..Glia, we are beginning to see, knit all the cellular components of the nervous system into a functional network (Fields, 2009, p. 309).

Neuroscientist Dr. Andrew Koob considers glial astrocyte cells fundamental to human creativity and imagination. In his book, *The Root of Thought*, Dr. Koob notes that neurons require sensory stimulation to fire electrical impulses, whereas astrocytes do not always require such external sensory stimulation and can randomly release small calcium "puffs" that can lead to stronger "calcium waves," which stimulate a wider area of neural activity. According to Dr. Koob, this unique feature of astrocyte cells could be the basis for the human capacities of deep thought, visualization, and imagination. Dr. Koob also notes that it is the human cortex – which is capable of higher level thinking and imagining – that has the largest and most abundant level of astrocytes compared to any other species within the animal kingdom (Koob, 2009).

In comparative research on mammalian brains, neurophysiologist Suzana Herculano-Houzel and her colleagues at the Instituto de Ciencias Biomedicas/Universidade Federal do Rio de Janeiro discovered "emerging evidence that the glia/neuron ratio varies uniformly across the different brain structures of mammalian species that diverged as early as 90 million years ago in evolution. . . [which]. . . highlights how fundamental for brain function must be the interaction between glial cells and neurons" (Herculano-Houzel, 2014, p. 1377).

Through a biochemical link with neurons at the synaptic gap (the microscopic space between adjoining neurons at the synapse) glial cells deploy gliotransmitters to help regulate the strength or weakness of synaptic transmissions between neurons (Sahlender, Savtchouk & Volterra, 2014; Clark et al., 2015). In other words, glial cells contribute significantly to processes that were earlier thought to be controlled by neuronal impulses alone.

We conclude from the above information that since learning and memory are generally believed to be established by the strengthening of interconnected networks of synapses, as well as by the formation of new brain cells with new connections, a strong neuroscience-based case can be put forward that glial cells and neurons are true partners in brain information processing. And, given the direct responsiveness of glial cells to environmental circumstances, it is apparent that an environment or context will have a strong effect on learning.

Experiential learning by natural design

Another type of glial cell called an oligodendrocyte functions to build up a fatty insulation layer – called a myelin sheath – along the nerve's axon extension. This myelination process permits much faster transmission of electrochemical pulses (from an initial speed range of 0.5–10 meters/sec up to 150 meters/sec) within the brain, facilitating superior integration of sensory, motor, and cognitive functioning (Purves et al., 2001).

Myelination also significantly decreases recovery time for neuron firing – permitting up to a 30-fold increase in frequency – according to child psychiatrist Dr. Jay Giedd of the National Institute of Mental Health (Giedd, 2009). The downside of this much faster transmission speed is a loss of neural flexibility because the myelin sheath restricts the growth of new branches from the axon. One might imagine, in a metaphorically similar way, how the thickening bark on the lower trunk of a maturing tree outdoors serves to protect it but it also restricts new branches sprouting in that area of the trunk.

This myelination process continues through childhood and into early adulthood, and it is the higher-level functioning forebrain regions of the neo-cortex that are last to complete significant myelination (Stiles & Jernigan, 2010). Neuroscientists have observed that myelination, like synaptic pruning, is also activity-dependent (Markham & Greenough, 2004). In effect, the brain's "plasticity" results not only from synaptic pruning but also from myelination – both of which are influenced by what we do.

Therefore, given this biological dynamic, it is apparent why extensive and diverse experiential stimulation would be highly beneficial for young people – especially during sensitive periods of brain development. Later in this paper and in Part Two, we make a more detailed case that learning in relatively wilder places may provide the most extensive and diverse experiential stimulation suited to the growing brain. In the next sections, we look further at the connection between the human brain and the non-human world.

Continuum of connectivity

The preceding sections considered the brain in the way it is normally studied in neuroscience – as something that can be understood by looking at carefully. To some extent, this is true. But how are the two distinct and interconnected forms or brain processes connected with the world? The answer to this question leads in the direction of why learning in wild places may be so significant.

It is probable that a very fast neuron-based electrochemical signaling evolved to improve reaction speed and the odds of survival – for example, to avoid being eaten and to successfully hunt and to defend oneself and others from harm. But how is it possible to explain the much slower brain signaling exhibited by astrocyte cells, which are slower than their very fast neuron partners by as much as 10,000 times (Oberheim et al., 2009)? What was their evolutionary "value-added"? One possible answer for the co-existence of a two-speed brain signaling/information processing system can be found in the nature of the interconnection between breath, blood, body, and environment.

In the late 19th century, scientists discovered that blood flow increased to specific areas of the brain in response to related functional activity (Mosso, 1882; Roy & Sherrington, 1890). In recent times, neuroscientists established that astrocyte cells are physically involved in regulating blood flow volume to localized areas of the brain through the faculty of "neurovascular coupling" (Harder, Alkayed, Lange, Gebremedhin, & Roman, 1998; Metea & Newman, 2006; Pellerin & Magistretti, 2004). In neurovascular coupling, the "end-feet" of the astrocyte's multiple projecting arms physically wrap around blood vessels that infuse the brain (arterioles), and as a consequence are able to constrict or dilate arterioles to control blood flow volume (Haydon & Carmignoto, 2006). When activated neurons release neurotransmitters into the synaptic gap, this also triggers the release of calcium by the astrocyte cells. Using *in vivo* (within living body) imaging, neuroscientists observed that elevated calcium ion (Ca2+) levels can result in the secretion of vasodilatory material at the astrocyte's end-feet, expanding arterioles and allowing more blood to flow into that area of the brain (Howarth, 2014; Zonta et al., 2002). Significantly, this sequence of cellular level events only happens "when [neurons] get excessively excited during bursts of activation," according to neuroscientist Dr. Baljit Khakh (Haustein et al., 2014). A press release by the National Institute of Neurological Disorders and Stroke (NINDS) comments that "these findings suggest that astrocytes . . . may act as a switch that reacts to large amounts of neuronal activity by raising their (astrocyte) levels of calcium. These calcium increases occur over multiple seconds, a relatively long time period compared to that seen in neurons" (NIH, 2014). The influx of calcium ions into the astrocyte cells can also activate "calcium-waves," a much wider area of intracellular communication (Araque et al., 1998). In other words, the direct responsiveness of glia cells to environmental stimuli may influence the literal 'flow of thought.'

Astrocytes also respond to higher levels of acidity in the blood (from too much carbon dioxide) and can release chemicals that stimulate neurons to accelerate respiration, and thus increase blood oxygenation to "help maintain blood and brain pH and partial pressure of CO2" (Gourine et al., 2010, p. 571). And more recent research that investigated the functional oxygen sensitivity of astrocytes in rats and mice demonstrated that “astrocytes are functionally specialized CNS [central nervous system] sensors tuned for rapid detection of physiological changes in brain oxygenation” (Angelova et al., 2015, p. 10,460).

From the above, we hypothesize that the existence of astrocyte-related phenomena, such as two-speed brain signaling, neurovascular coupling, and brain oxygenation sensing, reflects the tight but slower information exchange between astrocyte brain cell functioning and the body’s respiratory, digestive, endocrine, muscular, integumentary, reproductive, and especially cardiovascular systems. The nature of this biological connection between the brain, the rest of the body, the world that contains them, and the critical role this connection plays in cognition has emerged as the area of scientific inquiry called *embodied cognition*.

A feeling intelligence

In his book, *Descartes’ Error: Emotion, Reason, and the Human Brain*, neurobiologist Dr. Antonio Damasio elaborates on this integrative approach to the understanding of cognition:

> . . . human reason depends on several brain systems working in concert across many levels of neuronal organization, rather than a single brain centre. Both ‘high-level’ and ‘low-level’ brain regions, from the prefrontal cortices to the hypothalamus and brain stem, cooperate in the making of reason. The lower levels in the neural edifice of reason are the same ones that regulate the processing of emotions and feelings, along with the body functions necessary for an organism’s survival. In turn, these lower levels maintain direct and mutual relationships with virtually every bodily organ, thus placing the body directly within the chain of operations that generate the highest reaches of reasoning, decision-making, and by extension, social behaviour and creativity. Emotion, feeling, and biological regulation all play a role in human reason” (Damasio, 1994, p. xvii).

In working with patients unable to experience emotions/feelings as a result of brain damage, Dr. Damasio came to understand the degree to which a feeling handicap compromises rationality, and, by inference, the important role of emotion within reasoning. Recent research by psychologist Prof. Denise de Ridder and colleagues suggests that “visceral drives and other ‘hot states’ (can) facilitate advantageous decision-making when these decisions are complex and long-term outcomes are uncertain, such as when delayed benefits are involved” (de Ridder, Kroese, Adriaanse, & Evers, 2014).

An (f)MRI creativity study conducted by researchers at Stanford University uncovered a positive correlation between enhanced creativity and greater engagement of the limbic systems cerebellum (“the little brain”), and a negative correlation with creativity when there was greater involvement of the left prefrontal cortex (Saggar et al., 2015). Significantly, greater involvement of the cerebellum in thinking – the functions of which include integration of sensory perception and co-ordination of movement – improved creative problem-solving. Conversely, greater involvement by the higher-level, executive control centers of the brain in creativity tests worsened test outcomes.

Psychologist Dr. Daniel Goleman, in his book *Emotional Intelligence*, notes that "emotions are, in essence, impulses to act, the instant plans for handling life that evolution has instilled in us. The very root of the word *emotion* is *motere*, the latin verb 'to move,' plus the prefix 'e-' to connote 'move away,' suggesting that a tendency to act is implicit in every emotion" (Goleman, 1995, p. 6) – even if an emotion is internally repressed rather than expressed. This evolutionary understanding of emotion as a dynamic system seeking to "move away" from external negative stimuli – but also to connect closer with positive stimuli – underlines how emotional ways of knowing function as a communication bridge between the brain, body, and environment beyond the skin. Elaborating on this deep inter-connectedness, Dr. Goleman notes that:

> From the most primitive root, the brain stem, emerged the emotional centers. Millions of years later in evolution, from these emotional areas evolved the thinking brain or "neocortex." The fact that the thinking brain grew from the emotional reveals much about the relationship of thought to feeling; there was an emotional brain long before there was a rational one (p. 10).

Later, Dr. Golman writes:

> . . . as the root from which the newer brain grew, the emotional areas are intertwined via myriad connecting circuits to all parts of the neocortex. This gives the emotional centers immense power to influence the functioning of the rest of the brain – including its centers for thought (p. 12).

Given this sequence in brain development, neuroanatomist Dr. Jill Bolte Taylor's claim that "we are not thinking creatures that feel, biologically we are feeling creatures that think" is credible: the first area of the brain to receive incoming sensory information from the environment is the emotion-oriented limbic system (Taylor, 2008, pp. 08-12).

We conclude from the preceding that feeling is closely linked to and an integral part of thought, and that the influence of glial cells on neuronal activity connects the processes narrowly described as thought to a much broader world.

Heart, blood, breath

The connection of feeling/emotion to the physical body – especially through changes in heartbeat, blood flow, and rate of breathing – is close. Beating 100,000 times per day on average, every day the human heart pumps roughly 7,600 litres of blood through the circulatory system's approximately 96,500 km of vessels, oxygenating and supporting the body's cells (Daniels, Stein, & Gura, 2007). The rate and force at which the heart pumps blood through this vast and intricate system – as well as the elasticity of blood vessel walls – determines blood pressure (Moser, 2007). Through changes in rate of breathing, blood oxygenation, and blood pressure/flow, the heart and the rest of the circulatory system engage *the whole body* in response to negative and positive stimuli from the external environment. Sometimes this influence is subtle and/or unconscious, but sometimes not, as we can observe in the powerful sympathetic nervous system response triggered by real or perceived fear – the 'fight or flight' response (Cannon, 1929). But whether or not the external environment contains a human-directed threat, such as a car approaching at high speed, the influence of the environment on the limbic system and the brain's processes of thought is undeniable.

Author, psychiatrist, and All Souls Fellow, Dr. Ian McGilchrist states, "Emotion is inseparable from the body in which it is felt, and emotion is also the basis for our engagement with the world" (2009, p. 66). Indeed, a significant evolutionary adaptive advantage of emotions and felt experience – whether interpreted positively or negatively – is that this type of knowing is grounded in the reality of the moment. This is because sensory information from the world beyond the human body – which helps to shape different human feeling states – is processed in real time. In effect, the more-than-human world and human perception effectively intersect in present moment consciousness and not in consciousness dwelling on remembered past events or on imagined future experiences. Inattention to the unfolding reality of immediately embodied sensory information is also potentially life threatening and/or selectively disadvantageous insofar as it ignores real environmental dangers and opportunities. There is, in addition, a psychological risk that "too much future" oriented consciousness can sometimes lead to paralyzing anxiety, while, conversely, "too much past" remembered consciousness could – depending on a person's prior life experience – increase the risk of energy draining depression. Thus, in human evolution terms, attention to felt experience in the present moment may not only have helped to improve odds of physical survival, it may also have provided psycho-social adaptive advantage.

Through the very long process of evolution, humans were progressively fine-tuned – through the senses and emotionally/cognitively – through experiential learning in wild natural environments. Harsh necessity forced early humans to quickly adapt – or perish – to rapidly changing environmental conditions, and through this process our species became expert at adaptation. One of the ways this enhanced adaptive capacity was expressed was in the ability to learn quickly and effectively through special periods of heightened brain neuroplasticity – such as in early infancy and during the developmental period known as the adolescent growth surge (or spurt).

Adolescent growth surge & "arrested development"

The dramatic physical development changes that are known in combination as the adolescent growth surge generally start around ages 8–10 for girls and 9–11 for boys, and this stage typically lasts 4 to 5 years. Whereas in the past, the pubertal period was viewed as a time of rapid physical growth involving the development of secondary sexual characteristics, it is now also understood as a time of significant brain re-organization and psychological change (Blakemore, Burnett, & Dahl, 2010; Giedd, 2009). To explain why this might be occurring once again in early adolescence, Dr. Giedd suggests that the "increased connectivity and integration of disparate brain functions, changing reward systems and frontal/limbic balance, and the accompanying behaviours of separation from family of origin, increased risk-taking, and increased sensation seeking have all been highly adaptive in our past and may be so in our future" (Giedd, 2009, p. 341). There is indeed some evidence that new neurons formed in the limbic and hypothalamic regions of the adolescent brain during puberty are functionally integrated into wider neural circuits – pointing to the possibility that "emotional needs in teens may spur the growth of new brain cells" (Lieff, 2013; Mohr & Sisk, 2013).

The release of adolescent hormones during puberty stimulates the amygdala, which plays an influential role in emotional response. In a June 2014 article on teens published in the New York Times, clinical psychiatrist Dr. Richard Friedman wrote that a "maturational gap between the amygdala and the prefrontal cortex in humans has been found across mammalian species, suggesting that this is an evolutionary advantage" (p. SR1). In the individual adolescent, however, it means that "adolescents have a brain that is (developmentally) wired with an enhanced capacity for fear and anxiety, but is relatively underdeveloped when it comes to calm reasoning" (p. SR1). Neuroscientist Jay Giedd observes that contrary to popular perceptions:

> The teen brain is not defective. It is not a half-baked adult brain either. It has been forged by evolution to function differently from that of a child or an adult. Foremost among the teen brain's features is its ability to change in response to the environment by modifying communication networks that connect brain regions (Giedd, 2015, p. 32–37).

Accepting the argument that there was/is an evolutionary advantage to a second stage of significant brain transformation, why does child/adolescent development exhibit a slowdown between the two main periods of accelerated physical growth/enhanced synaptic pruning? A slowdown in rate of growth so distinct that this period is sometimes described as one of "arrested development." Why are physical growth and enhanced neuroplasticity not processes of continuous and steady growth?

One theory for the evolutionary advantage of arrested development was that prehistoric children who expressed delayed physical growth after weaning and before puberty would have had lower caloric energy requirements and thus have been in less direct competition with adults over food resources or other advantages. Remaining physically smaller and dependent for a longer time also would have increased odds of survival during periods of food scarcity or physical vulnerability, and extended the opportunity to learn more advanced communication and life skills under safer conditions (Janson & van Schaik, 1993). Adding further credibility and refinement to this "slow growth" theory are field research studies done in two contemporary foraging societies – the Ache of eastern Paraguay and the Dobe Ju/'hoansi of Botswana – by anthropologists Michael Gurven and Robert Walker. The data from their research studies suggest that "slow human growth followed by rapid adolescent growth may have evolved in response to rising human fertility rates in a foraging niche where early increases in body size are sacrificed for greater investments in brain growth and immune function" (Gurven & Walker, 2005, pp. 835-841). In effect, arrested development would have allowed parents to successfully raise greater numbers of surviving children. Children's slower physical body growth would have permitted diversion of the child's internal energetic resources towards cognitive and immune system development for survival advantage (Gurven & Walker, 2005). But for modern education, this also suggests a particular phase of neuroplasticity that might provide significant opportunity for learning.

Educational opportunity

The adolescent growth surge stage represents an exceptional evolution-programmed opportunity to engage youth in experiential nature/wilderness activities that can noticeably enhance maturation and learning engagement. The middle school years of education (grades 7 & 8) are those that align closest to the early adolescent growth surge period, and, not coincidently, are often also the years when some – and in certain communities far too many – young adolescents lose their enthusiasm for school and begin to progressively disengage. The First National Report (2009) by the Canadian Education Association (CEA) revealed that only 37% of secondary school students were intellectually engaged in their language arts and math classes, and that "levels of participation and academic engagement fall steadily from Grade 6 to Grade 12, while intellectual engagement falls during the middle school years of this period and remains at a low level throughout secondary school" (Willms, Friesen, & Milton, 2009).

With more life experience, most adults come to a deeper appreciation that success – however defined – is a long game and that the ability to adapt well to change and persevere are important personal qualities. From a similar perspective, Dr. Goleman writes that:

> . . . academic intelligence offers virtually no preparation for the turmoil – or opportunity – life's vicissitudes bring. Yet even though a high IQ is no guarantee of prosperity, prestige, or happiness in life, our schools and our culture fixate on academic abilities, ignoring emotional intelligence, a set of traits – some might call it character – that also matters immensely for our personal destiny. Emotional life is a domain that, as surely as math or reading, can be handled with greater or lesser skill, and requires a unique set of competencies. And how adept a person is at those is crucial to understanding why one person thrives in life while another, of equal intellect, dead-ends: emotional aptitude is a *meta-ability*, determining how well we can use whatever skills we have, including raw intellect. This of course does not mean

> academic effort and excellence are not of great value, but simply that there is much more to a good education than intellectual development and knowledge (Goleman, 1995, p. 36).

Inspired by the work of Dr. Damasio and Dr. Goleman on emotional intelligence, and with leadership from CASEL (Collaborative for Academic, Social and Emotional Learning), efforts to advance evidence-based practices in social and emotional learning (SEL) are gaining support from school boards and policy-makers across North America. A 2011 meta-analysis of school-based social and emotional learning interventions published in the journal *Child Development*, and involving over 270,000 students from kindergarten through high school, revealed that "compared to controls, SEL participants demonstrated significantly improved social and emotional skills, attitudes, behavior, and academic performance that reflected an 11-percentile-point gain in achievement" (Durlak, Weissberg, Dymnicki, Taylor, & Schellinger, 2011). And, when Columbia University's Center for Benefit-Cost Studies of Education analyzed six prominent socio-emotional learning interventions, they estimated that for every one dollar ($1) invested in effective socio-emotional educational programs, the average return on investment was eleven dollars ($11) (Belfield et al., 2015).

Perhaps much greater social, environmental, and economic benefits can be found in combining the interests addressed by CASEL with the benefits of learning in wilder places. Given the many challenges today in education and around healthy child development, it is worth considering if a brain science and evolution-informed wilderness immersion approach to learning – for at least one semester during the transformative adolescent growth surge period – would sustain and perhaps in some instances recover student learning interest and academic engagement. In taking advantage of this particular phase of rapid brain change in the context of new understandings of glial/neuronal processes, might a phase of wilderness immersion also enhance physical, social, and emotional health, thereby creating a stronger foundation for achievement and well-being in future stages of education, relationship, and livelihood? We will seek to address these questions in the next sections of Part One and in Part Two.

Embodied perception/extended cognition

How the brain and mind are understood shapes teaching method and practice. The conventional computational/representational model considers the brain and mind as essentially the same. This perspective views the brain as a sort of biological computer inside the skull, with mind as software programs running entirely within the brain and only processing representations of reality. A number of thinkers have directly challenged this view. For instance, in their paper *The Extended Mind*, philosophers Andy Clark and David J. Chalmers propose an alternative model they call "active externalism." In their view, the mind and surrounding environs act as a "coupled system," with an "active role of the environment in driving cognitive processes" (Clark & Chambers, 1998). Cambridge University biologist Dr. Rupert Sheldrake also persuasively argues for a "field theory of minds" (Sheldrake, 2012). And in his book *Science Set Free,* he quotes the philosopher Arva Noe, who writes that, "We are in the world and of it. We are patterns of active engagement with fluid boundaries and changing components. We are distributed" (Sheldrake, 2012, p. 220).

This model of mind extended into the world is further supported by research on embodied perception. In his recent book, *The World Beyond Your Head*, University of Virginia professor Dr. Matthew Crawford observes that ". . . the possibility of movement that our bodies provide – [is] no mere accessory to perception, but rather constitutive of the way we perceive. . . one has to be able to explore a scene from different perspectives to perceive what remains the same about it – its nature and structure, regardless of perspective – and locomotion is an indispensable part of this process" (Crawford, 2015, pp. 48–49). Matthew Crawford convincingly challenges the metaphor for perception as representing multiple still photographs from which "inferences and representations" are computed within the brain. According to Dr. Crawford, this older model of perception fails to capture the complexity of what is rapidly unfolding in present moment reality and is quite simply ". . . not adequate to the task of specifying the world" (p. 50), whereas a moving observer can do so. In effect:

> We think through the body. The fundamental contribution of this school of psychological research [embodied perception] is that it puts the mind back in the world, where it belongs, after several centuries of being locked within our heads. The boundary of our cognitive processes cannot be cleanly drawn at the outer surface of our skulls, or indeed of our bodies more generally. They are, in a sense, distributed in the world that we act in (Crawford, 2015, p. 51).

Thus, while the brain remains in the body, the mind includes integration and interaction with regions outside the body. This understanding of mind coupled with and extended into something beyond the body has a precursor in the intense nature of the baby/mother connection. Shankar relates how "the primary caregiver serves as an 'external brain,' up-regulating and down-regulating the baby. Dyadic experiences are vital for: sensory integration, sensory/motor coordination, emotion regulation, effortful control, sustained attention" (Shanker, 2010, p. 14). Neuropsychiatric specialist Dr. Jean Clinton of McMaster University's Offord Centre for Child Studies suggests that since synaptic pruning is also directly affected by emotional relationships with caregivers, it would be accurate to say that "love builds brains. . . literally" (2009, p. 672).

Another way of viewing this state of infant/mother co-regulation would be to say that, after the baby is born, the baby/mother actively seek to re-establish or maintain the intense connection previously experienced during the "inner wilderness" of the womb/mother in order for the baby to continue thriving in its development. Since this powerful baby/mother co-regulation occurs during the first major period of synaptic pruning, an intriguing question is whether that first intense "dyadic" connection could later function as a brain development template for the next significant period of synaptic pruning that occurs in early adolescence. And if indeed it does, could stronger re-connection with another complex intelligent matrix – this time in the form of wilderness as introduced by wise teacher-guides – provide the young person undergoing brain reorganization and maturation with the enriched sensory stimulation, connected experiential learning, and social awareness that in turn fosters the optimal development of emotion- and self-regulation – as was the case during the baby stage of brain development?

In effect, our evolution was shaped in a transformative connectedness to the natural world and to other species for the survival advantage this provided. Thus, among the many reasons for valuing and protecting the natural world – the strongest of which being inherent worth – can be added the opportunity it provides for the understanding of other aspects of reality not available to the more narrowly calibrated human sensory system. And this is a very strong neuroscience and philosophical argument for learning, especially during phases of rapid brain change such as the adolescent growth surge, in wilder places. The degree of variety that can be experienced in more human-controlled environments and culture, while impressive and sometimes magnificent, cannot fully provide the ecological variety to meet the biologically primed developmental needs of adolescents.

In the absence of such a powerful connection/re-connection need and opportunity, perhaps the default alternative has become the simulated adventures of the screen-based virtual reality world. If so, this would certainly explain the intensely compelling – and too often compulsive – quality of virtual reality gaming and digital screen time absorption by an adolescent brain/body, which at this stage is optimally developmentally primed for transformation. What then are some of the larger implications to a child's cognitive/emotional and physical development if they continue to be "machine-made" in this manner? To what extent could some negative effect be attenuated by greater connection and involvement with the natural world, especially during the critical childhood and adolescent growth developmental stages?

Attentive receptivity

While there is no evidence in their paper that Clark and Chalmers were particularly considering nature/wilderness in their conception of active externalism, their theory leans towards that of many Indigenous perspectives on consciousness or "knowing." One of the authors of this paper works extensively with Teme-Augama Anishinaabe elders. Many of the stories they tell suggest an understanding of the world in which human consciousness communicates with and extends into the greater whole – a mode of being that could be described as "attentive receptivity" (Beeman, 2006; Beeman & Blenkisop, 2008).

Attentive receptivity is much more than simply a deepened use of the senses – the redirected attention to the world with a more sense-oriented awareness. The posited state of attentive receptivity refers to a different ontological ("state of being") mode: it is only ever enacted, and can never be completely encompassed through means of representational concepts such as we are attempting here. It is enacted in the lived playing out of people's relationship with the more-than-human world. In a mode of attentive receptivity, the human participant in the ecosystem acts to bring consciousness into the unfolding pattern of the world. This mode of being shifts human position from an anthropocentric focus of attention/direction and use, for end-gain, to one of being an eco-centric attender, whose role is one of perceiving clearly, receiving the special language of nature, and acting in harmony with the world. This state of being also leads to a different epistemological ("way of knowing") position as well: which is one of listening, relinquishing will-directedness, not assuming species superiority, and attuning to feeling states.

These alternative and diverse views of the brain, mind, and perception – and therefore modes of being and knowing – are the exception in modern western society and, in consequence, its mainstream educational practices. Instead, what tends to persist is a compartmentalized model where brain and mind are essentially seen as the same, and as largely engaged in computational and representational information processing. It is essential that this view – and some of the educational practices it has consciously and unconsciously shaped – be updated. An enhanced pedagogy emerges from a perspective that views brain and mind as different, and which therefore appreciates that the brain's evolutionary learning potential is best realized through a more balanced interaction with the natural world and in a community that exists outside of classroom and school building walls. With this expanded view of the brain and mind, the wider world, including the more-than-human, with its infinite variety, adaptability, and unpredictability, is available to support children in deep learning and fuller development.

Chief Ota K'Te (Luther Standing Bear) spoke of the world outside of classroom walls, and in his eloquent description it becomes evident why this form of learning is so developmentally powerful:

> Knowledge was inherent in all things. The world was a library and its books were the stones, leaves, grass, brooks, and the birds and animals that shared, alike with us, the storms and blessings of earth. We learned to do what only the student of nature learns, and that was to feel beauty. We never railed at the storms, the furious winds, and the biting frosts and snows. To do so intensified human futility, so whatever came we adjusted ourselves, by more effort and energy if necessary, but without complaint (Standing Bear, 1978, p. 194–195).

Wilderness tuning

In a research study entitled *Creativity in the wild*, psychologists Dr. Ruth Atchley and Dr. Paul Atchley from the University of Kansas, and psychologist Dr. David Strayer from the University of Utah, documented a remarkable 50% improvement in higher-level cognitive function in test participants after they took part in a four to six day wilderness hiking trip (Atchley et al., 2012). The study acknowledged that some of the documented cognitive benefit could have been the result of decreased exposure to attention-demanding/distracting technologies, since all participants agreed to abstain from using them during the trips. However, the researchers also concluded that one possible mechanism for the significant cognitive improvement could have been that nature immersion encourages "soft fascination," which engages areas of the brain that are "active during restful introspection," and that the activation of these "default mode networks" of the brain allows the overused higher-thinking frontal lobe area of the brain to recover. This process of recovery from an excessive amount of "directed attention" in turn was thought to be what permitted the improved creativity (Atchley et al., 2012).

A complementary interpretation of the results of Atchley et al.'s study would be that wilderness journeys excel at fine-tuning the brain because the brain is optimally tunable while it is immersed in the environment/activities through which its basic functional design dynamically evolved. The design factors at play could be as simple as reduced levels of pollutants and increased levels of exercise and oxygenation, thus affecting glia and neural signaling, and thus also neuronal signaling, as described in an earlier section. Or, they could be much more complex, as in the biological effects of certain tree species' biochemical contribution to the surrounding atmosphere, as noted in the work of Dr. Diana Beresford-Kruger (2003). Or, it could be attentional, following the insights of Dr. Iain McGilchrist, whose work is introduced later in this paper. Or, they could be conceptual, in, for example, the awareness of one's life as it is interlaced with the natural world. In any case, immersion in wilderness environments naturally entrains greater sensory awareness, including an attentiveness that is instinctively vigilant in present moment awareness in order to detect potential sudden danger or opportunity. And it is in this moment-by-moment, heartbeat-by-heartbeat, felt, sensory attention to the world that we hypothesize the brain to be hemispherically re-balanced in a manner which we discuss later in this paper. We propose also that it is as a function of this (re)tuning process – which in part also involves better balancing the relative amount of time spent inhabiting past or future oriented consciousness versus present moment consciousness – that better cognitive functioning results.

The wilderness effect

Psychologist Robert Greenway has extensively explored this deeper human–nature relationship – and what has been termed "the wilderness effect" – on people immersed for set periods of time in wilderness journeys (Greenway, 1993). (While we recognize that the term "wilderness" is contested, we mean by this approximately, relatively less human-influenced places.) As part of his extensive research at Sonoma State University, Greenway and his team of researchers developed a wilderness expedition program that over the course of 22 years brought 1,380 participating students and others to typically two to three week-long wilderness journeys. Among the many observations and findings that emerged from their studies was insight into different "modes of being" in wilderness, as well as the mental state of expedition participants as they crossed through what Greenway describes as a "psychological boundary" into wilderness – a very different experience from crossing the physical boundary between urban environments and wilderness. As this psychological boundary was crossed, cognitive individualism was replaced by a more participatory, full-being experience involving feelings of expansion/ reconnection.

To aid in achieving and enhancing the experience of the wilderness effect, the program facilitators were deliberate in designing wilderness journey travel that involved special pre-departure preparations, not specifying daily end destinations, ensuring periods of silent walking, and optional solo experiences. All of these experiences were designed to most immediately connect participants to the world of which they were a part. As previous sections of this paper show, the embodied nature of cognition – and the physiological effects of different environmental factors – may have contributed to this effect.

A 2015 research study published by the *Journal of Personality and Social Psychology* uncovered a positive connection between awe (including that inspired by nature experiences) and the development of such pro-social behavior as caring, sharing, and assisting (Piff et al., 2015). The researchers found that the ". . . emotional response to perceptually vast stimuli transcend(s) current frames of reference" and theorized that the observed increase in ethical decision-making and empathy was the result of a 'diminishment' of individual self-centeredness. . . in the presence of something greater than self" (p. 883).

We will deal in more detail with the groundbreaking work of Dr. Iain McGilchrist's *The Master and his Emissary* (2009) in Part Two of this paper. However, it is useful to introduce one central idea from his work in this context. Sparked by the physiological evidence of hemispheric asymmetry in the human brain, Iain McGilchrist reexamines arguments for hemispheric difference. He advances an evolutionary explanation for the two different forms of attention orientation that characterize the operational mode of each hemisphere. In dual attention task mode, the left cerebral hemisphere engages in a more detail-focused attention directed at accomplishing a specific in-future-time goal that improves survival prospects, while the right hemisphere is simultaneously engaged in more of a whole body, multi-sensory vigilance that is quickly responsive to environmental dangers and opportunities suddenly emerging in-present-moment time. What interests McGilchrist in the asymmetry of the brain is the "how"– the manner in which the two hemispheres of the human brain differently interpret the world. McGilchrist outlines historically how and why the initially subordinate function of the "left hemispheric" mode of attention and being came to dominate the "right hemispheric" mode of attention and being. These are important ideas for education, because the world that is perceived is in significant ways shaped by the mode of perceiving it. It is worth underlining that this investigation of cerebral hemispheric difference is not about "what" the two hemispheres of the brain do: this previous view derived from a machine-based model in which different functions were understood to be located in specific regions of the brain. This view was shown to be erroneous by the advent of new brain imagining technology, which showed activity and redundancy for various functions throughout the brain. In educational terms, the implications are significant because much of current instruction in schools – indeed, what is understood to be knowledge – is heavily weighted towards "left hemispheric" functioning, which, for reasons we further explore in Part 2, limits optimal learning and maturation especially during the pre/early adolescent developmental stage.

The kind of learning that occurred in Dr. Greenway's wilderness immersion courses and described as "the wilderness effect" cannot be reduced to simple brain function. Powerful re-framing experiences in wilderness that help diminish the typical strong self-centered orientation of children (something developmentally normal in young children but problematic in adults) promote healthy socio-emotional maturation in tweens insofar as they enable them to function more effectively within social groups. Could this be because wilderness experiences help to better balance the cognitive engagement of the left and right cerebral hemispheres – thus reducing the dominance of the more self-defining and self-referential left hemisphere? Reinforcing this shift and helping to consolidate behavioural learning is the fact that small group interactions are extended over time and contained by the crucible of a wilderness journey.

Given the history of millions of years of an evolution-optimized brain, it becomes possible to appreciate why longer wilderness journeys such as those Dr. Greenway studied can enhance self-knowledge, and, as earlier-quoted studies of longer wilderness experiences show, the very capacity to think. Self-propelled and small group wilderness journeys that integrate extensive physical movement, in-the-moment multi-sensory processing, and adaptive learning under continually varying environmental circumstances, and with the addition of mature supportive guidance, create opportunities to enhance self-awareness, self-regulation, and discernment.

Conclusion of part one

This concludes Part One. In this paper, we have explored the connections between glial influence on neuronal activity; myelination, synaptic pruning, and experiential learning; the links between thought, feeling, and the world we humans inhabit; the significant brain changes of the adolescent growth surge and its implications for learning in wilder places. In Part Two, we begin with a deeper consideration of the significance of the human brain's hemispheric divide. We address psychosocial benefits to learning in wilder places. We identify *Journey Pattern Learning* therein as an ideal context for learning, and we make a proposal for wilderness immersion learning for middle school students.

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