

Specific Modes of Physical Activity and Cognitive Development in Children

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Recent times have seen a significant decline in the level of children's Physical Activity (PA).¹ This has led to a dramatic increase and earlier onset of preventable chronic health disorders also leading to negative psychological, behavioural and cognitive outcomes.^{2,3} Obesity maybe a relational factor in the inactivity related ill-health epidemic, whilst recent research suggests physical inactivity to be primarily causal.³ The trend towards early onset of illness related disorders associated with physical inactivity has been amplified by a move in advanced economies towards reduced PE and increased academic tasks in primary schools, based on the false hope of enhanced academic success.⁴ The reverse is most likely true leading to a double disorder of declining PA and reduced optimisation in academic performance.⁴ Regular doses of PA are protective against the onset of these disorders and can reverse the effects of physical inactivity related ill health if enhanced levels of PA is implemented.^{3,5}

The positive effect of PA in pre-adolescents cognitive and academic development is now well documented and serves to support the re-implementation of PA in primary schools.^{6,7,8} The traditional PE approach relating PA to childhood cognitive development and academic performance has centred on non-specific intensity based physical activities reliant on high metabolic cost and load forces (known as quantitative styles of PA). Examples of intensity based PA includes running laps and beep tests.⁶ The influence of quantitative programs on cognitive performance and organisation is proposed to centre on increased brain vascularity, non-specific cortical and sub-cortical neurogenesis and increased arousal levels of participants.^{6,7,8}

Qualitative Approach

A growing body of research supports the role of specifically designed physical activities related to the production of precise qualities of a movement sequence and is termed the "qualitative approach" (QA)^{9,10} (see box 1 available as appendix at www.aima.net.au). QA programs take into account unique human developmental

characteristics embedded in physical activities co-joined with cognitive development. QA in human movement is proposed to have a significant influence on cognitive development because of factors related to the extended period of human neuro-development and the immature state of the new born brain¹¹. Physical experience moulds neural connectivity during this early and extended developmental stage promoting a refinement and expansion of connections and pruning inactive neurones and their synapses.¹² Extended neuro-development and the rapidly expanding experience modulated paediatric brain promotes neuro-plastic changes in critical beds of human cognitive neurones, having future roles in executive functions and spatial organisation.^{9,10,11,12,13,14} In Australia organised school based programs such as the "Blueearth Approach" and teacher education based training illustrated by the "Essential Moves" and "Move to Learn" programs are at the cutting edge of qualitative styles of physical activities.^{15,16,17}

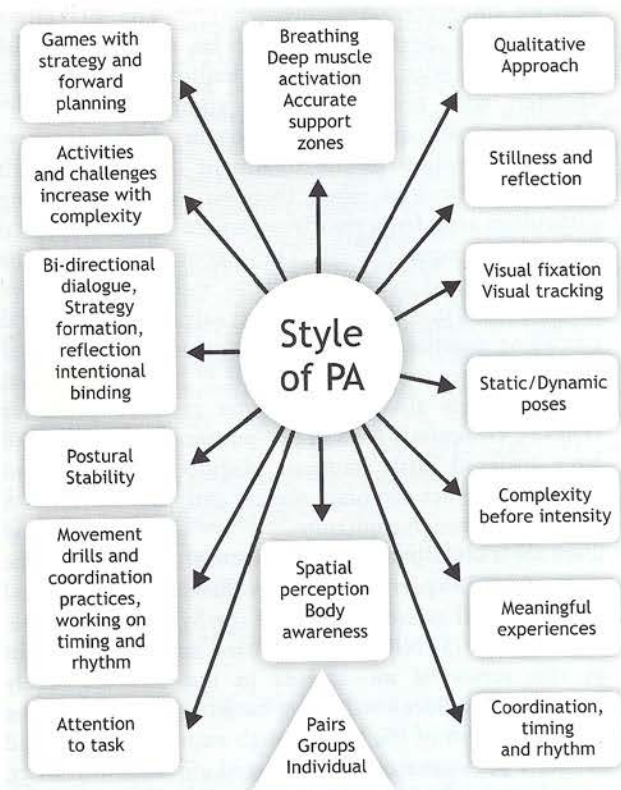
Neuro-development, Individual Domain Specific Expertise and "By Chance" Phenomena in Human Cognition

Children undergo a prolonged neural and physical maturation supporting the process of slow skills acquisition arising from low to medium based intensities. The development and refinement of locomotion, communication style, dexterity, eye movements, behavioural profiles and academic capabilities unique to modern Homosapiens requires a long period of organisation in the cognitive and executive control elements of the cerebral cortex as well as sub cortical and sensory absorption elements. Human cognitive functions also require advanced neural forward models (also requiring prolonged maturation) believed to exist within specific cortical and sub-cortical networks. Contributing factors in cognitive development from PA include the role of primitive reflexes and stereotypical postures, the style of movement, the accuracy of performance, the intention of the actor, concentration, attention, planning, attitude, beliefs and the consequences of the action. Timing, fluency, increased complexity, sequencing, Postural Stability (PS),



breathing, accurate intensity and endurance as well as other factors play crucial roles in QA PA interventions.^{9,10} Of paramount importance is the accuracy in which the child performs the movement task, the formulated movement intention matching age related cognitive development and the relationship of the participant to the task in connection with intrinsic and extrinsic motivations.^{9,10} It is then equally important the programs (either in direct contact with the children or via teacher/coach training by appropriate organisations) are conducted by well trained, skilled movement professionals who support many roles including coach, mentor and choreographer.

Figure 1. Activities included in QA to PA



The QA is proposed to provide greater specific modulation on the CNS due to unique phylogenic and ontogenic characteristics of modern humans.^{9,10} A crucial factor in the emergence of human cognition is related to the unique human trait of Individual Domain Specific Expertise (IDSE) arising from and bound to the extended infant neuro-development and emergent in modern human social groups (and not in sub human hominids).^{18,19,20} In the tribal group many experts often emerged with specialised expertise in specific fields of tribal life (usually associated with PA endeavours). This process has evolved and adapted for changing circumstances over time and is still a foundational principal of modern human existence.

Ancient human tribal groups exhibited generalised competencies for ADL's with numerous specific individuals expressing explicit capabilities beyond normal competency and into the realm of expertise (IDSE) and as proposed by Skoyles 1999^{19,20} and Sternberg 1999²¹ to be the underlying evolutionary pressure in the emergence of IQ. Cognitive processes supporting academic performance and IQ may have their origins in human evolutionary trait exposed in IDSE.

"By chance" natural abilities in children were noted and mentored so that future experts for tribal survival.^{19,20} "By chance" innate proclivity in human infants is proposed to be bestowed as an evolutionary characteristic for the unique human ability to form IDSE.^{19,20,21} However, the "by chance" individual characteristic can also "fall to the other side" so that "by chance" the infant is provided with reduced competencies and lower advantages – just as Darwin predicts. The Darwinian "by chance" phenomenon is dynamically expressed in the unique heterogeneous nature of all humans^{22,23} and in a small but important part explains the heterogeneous nature of learning and behavioural problems in infants and adolescents when natural proclivities by chance "fall to the other side".

IDSE is fostered and moulded by the post birth highly plastic and uniquely expanded brain.^{13,19} The plasticity of the human brain is most active from birth to puberty and relies on moderate to low intensity PA associated with QA

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to mould and modulate neural functional densities and connectivity in the expanding brain.¹¹ This process then serves as the organisational template for more complex processing during later stages of development and adapted to adult cognitive tasks. The highly plastic human brain responds to enriched environments with improved cognitive function and supports the role of movement and experience acquisition with IDSE model of human cognition.¹¹ Physical activities with meaning and consequence fuel the mechanisms for cognitive growth. Thinking, planning, acting and contemplating are interwoven phenomena separated only by temporal circumstance and bound by intention and the "deed".

The Unlink and Unlock Phenomena and Human Cognition

Humans are unique in the animal kingdom, in part because the fundamentals of intentionally directed movement and thought construction share common beds of neurones also responsible for the emergence of IDSE traits.^{13,14} Human styles of movement and the human styles of thought share complex neural connections allowing a common style of orchestration of thought and movement – known as the "Unlock and Unlink" (UU) strategy.^{13,14,24} Unlike all other animals, whose primitive thought processes and stereotypical actions are held separate and encapsulated within neural control networks, healthy adult humans, compared to all other animals, have the unique capacity to UU:

1. Sequential articular motion segments^{13,24,25,26}
2. The eyes from head movements to form specific "quiet eye" and visual fixation strategies²⁷
3. The jaw and epiglottis to produce controlled expiration with meaningful sound producing language,^{28,29} and
4. Mechanisms to manipulate information to produce meaningful thoughts predictions, plans and strategies.

The UU strategy for all parcels of movement and thought construction arises from common beds of neurones, with the most significant located in the dorso-lateral Pre-Frontal Cortex (PFC),³⁰ Posterior Parietal Cortex (PPC) uniquely expanded in the human brain linking the common functions of human cognition and intentional movements and provide the advanced forward predictive model simulations acting as the foundation of cognition.^{30,31,32,33} All other animals devoid of such expanded and sophisticated neural complexities also lack the ability to conduct any UU strategies.

Human Infants also use a Lock and Link (LL) strategy essential for normal development known as "lock down".²⁴ Both infant and animal LL strategies are based primarily on stereotypical and reflexive movement behaviours arising primarily from spinal cord, brain stem and midbrain structures, modulated by motor cortical zones. Animal and infant movement behaviours appear sophisticated and fluent but lack flexibility in application and adaptability when circumstances change and novel, complex environmental

challenges emerge. Infants' progress through this LL stage and it is through the activity of the above mentioned (uniquely expanded and connected in humans) neural structures and the possible inhibition by the PFC and PPC of motor and pre-motor cortical sites responsible for transitional (lock down) postural control strategies.

The Three Neurological Interdependent Levels Essential Human Cognitive Development

Three processes actively engaged in the infant neurology to support the physical experience modulation of brain function and cognitive development:

1. "Bottom Up" (BU) Sensory absorption and disambiguation.

The physical world is made up of energy fields available to animals through specific energy frequency responsive sensory receptors. The available specific energetic frequencies are absorbed by specific sensory receptor sites, then through the process of active pursuit of movement experience and accurate movement portrayal – the sensory signals are disentangled, topographical organised and amalgamated into an accurate neurological reflection of the specific stimuli that will be further processed up the hierarchical neurological chain.³⁴ Specific movements may influence the accurate integration of sensory inputs through exact performance of complex movements contributing mostly to the BU effect ^{35,36}. The BU process is the basis for many qualitative based movement programs illustrated by the "Blueearth Approach" (see www.blueearth.org.au) and sensory integration training.^{15,16,17,35,36} The BU effect on cognitive development may be more influential in children with learning difficulties compared to children with normal learning competencies.^{16,17,35,36} Therapists using qualitative approaches during sensory-motor integration in the treatment of children with learning difficulties often theorise that the learning difficulties arise from poorly organised or dysfunctional lower brain zones.^{16,17,35,36} These zones located in the brain stem and midbrain act to influence cognitive development in a BU fashion and can have a profound cascading negative influence when primitive reflexes are retained rather than inhibited.^{35,36,37,38} Some researchers and therapists alike also propose retained primitive reflexes, commonly seen in pre-pubescent children who have suffered birth traumas, plagiocephaly or infant stress syndromes are often significantly associated with vestibular based dysfunctions.^{16,17,35,36,38} In diagram 1 and 2 we see a child performing a postural manoeuvre. The accurate and expertly directed performance is proposed to inhibit still active portions of the Symmetrical Tonic Neck Reflex (STNR). It is proposed active engagement in this series of movements in non-directed freely performing children will often facilitate elements of the primitive form of PS, but through expert direction and accurate performance of a preferred movement strategy, conscious inhibition of the still active portions of the



Diagram 1 and 2 Illustrate the Set up phase of QA exercise designed to inhibit STNR and the end phase of the exercise.
Photo's courtesy of Essential Moves.

STNR will promote optimal movement performance, reduced ambiguity in body perception and formation of more accurate sensory maps, then facilitate greater efficiency in CNS for cognition functions.

2. Intermediate Processes: Organisation and Integration of Sensory Inputs

The Cerebellum (CB) and Basal Ganglia (BG) modulate cortical inputs by receiving a neural stimulus, influencing then returning to the same neurone (known as re-entrant stimulus) an altered and adapted afferent signal.³¹ The function of both sites has historically ascribed to the control and facilitation of human movements; however recent research supports the role of the CB and BG in higher cognitive functions. Koziol and Budding 2010 suggest the function of CB and BG in movement control persist and are utilised as similar strategic controls for emotional and cognitive regulation.^{31,32,33}

3. **Top down (TD) higher cognitive functions of dorso-lateral pre frontal cortex and posterior parietal cortex**
The PFC and PPC unify input from the BU process and re-structure the data into non-temporal information linking past experience, relevant current stimulus and task intentions into a functional and modular format for the solution to present tasks. The PFC and PPC are significantly linked to cognitive function and academic performance.^{39,40,41,42} The stimuli are represented in terms of their relevance to current behaviour rather than in terms of simple sensory properties.^{29,33} A range of different cognitive demands all appear to activate a similar network of frontal and parietal areas^{30,33,41} including attentional controls, forward planning, short term memory, PS, spatial awareness and numeracy.^{30,33,34,40,41,42,43} The PFC and PPC are connected to processing mechanisms for tasks requiring complexity or uncertainty.³⁰

The association cortex's can be influenced through PA via the modulatory effects of:

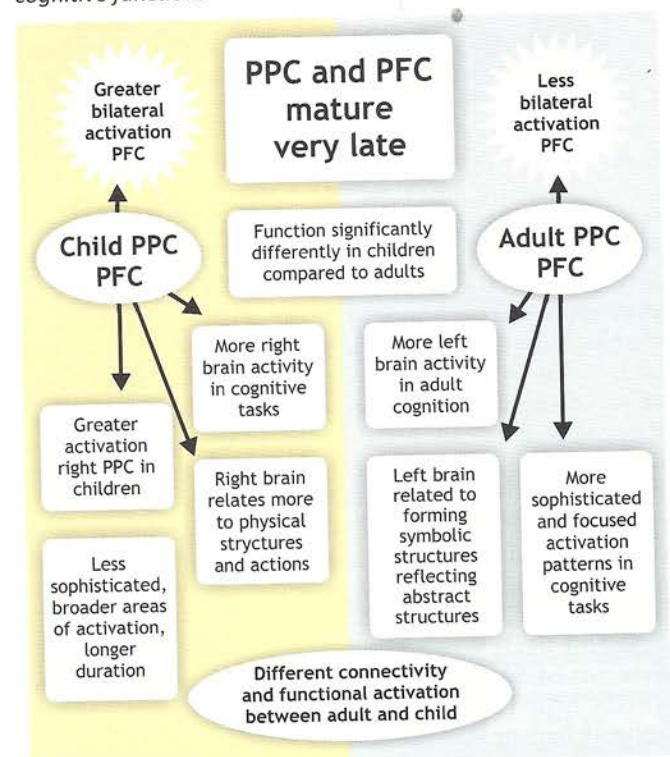
1. Movement Complexity,
2. Intentions,
3. Purposeful visual fixation and scanning strategies and
4. Constant accurate awareness of the task, the action space and the body embedded in the field of action.

The dorso-lateral PFC can be modulated by specific and accurate postural stability tasks with temporal sequencing, evolving complexities and attentional focus with functional task demands. The posterior parietal cortex can be facilitated by aspects of self and spatial awareness.

Pre-frontal Cortex and posterior Parietal Cortex in Pre-pubescent Children

In children the PFC and PPC utilise a significantly altered neurological firing pattern compared to adults with much larger areas of the bilateral PFC activity and a larger activation of the right PPC (areas more related to physical experiences) for cognitive tasks such as numeracy.^{30,33,39} Boys and girls have differently structured parietal and frontal cortex's, which is amplified by sex hormone influences and life experiences.^{12,44}

Figure 2. Differences between children and adults in cognitive functions



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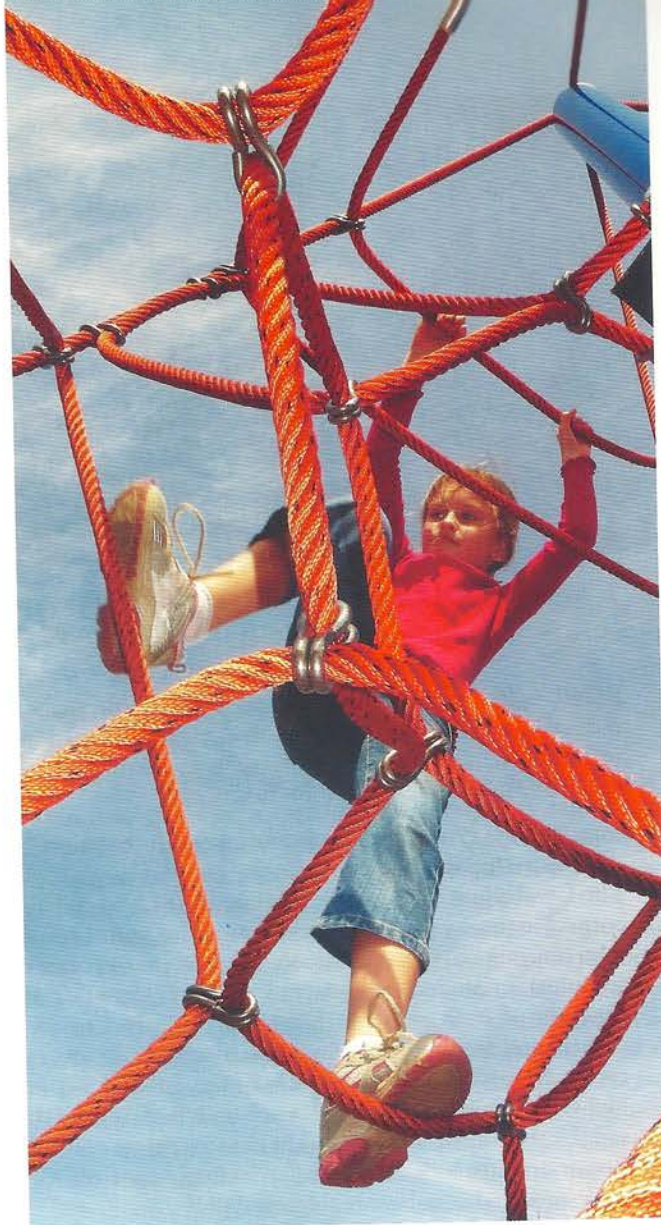
Boys and girls process sensory input differently, have different areas of higher cortical densities and connectivity and solve academic tasks in different ways.^{30,33,39} This should be taken into account when implementing movement for learning programs. It is important to note the PFC is active during tasks that are complex, novel or have multiple tasks. As the pre-pubescent child progressively experiences activities often for the first time and new tasks are also relatively complex, it stands to reason the PFC and PPC are significantly active during most PA tasks and is the process most effected by qualitative movement procedures.

Conclusion

It is clear and apparent that reduced physical activity levels in pre-pubescent children is having health and wellness consequences. Aligned to this phenomenon is a probable reduction in optimal cognitive and academic performance due to a reduction in age appropriate meaningful physical experiences. Recent evidence supports the use of physical activities for enhanced cognitive and academic performance. In particular a growing body of evidence supports the use of qualitative measures for enhanced, cognitive, behavioural and academic performance. QA assume many different forms and practices but are unified by the nature, intention and consequences of movement performances.

In children PFC and PPC neuronal beds activate in similar patterns for physical experiences and academic tasks (particularly numeracy), with activation patterns notably different to those exhibited in healthy adults. It is the authors' contention that intentionally guided specific movement tasks as part of a group activity, in pairs or individual lessons may enhance cognitive development, executive control and academic performance, over time. TD cortical brain structures may be particularly influenced by qualitative PA procedures and the effect supported and intensified by a combination of BU, TD and "intermediate" mechanisms.

Whilst Australian practitioners have a long pioneering history in the development and provision of qualitative physical activity programs^{15,16,17,45,46,47} greater research is needed in the use of qualitative measures for cognitive related outcomes in pre-pubescent children. Present sets of data are promising possible significant group and individual effects in qualitative PA programs for optimal cognitive development (See box 1). There is a need to understand more fully the complexities and application of qualitative based PA programs. It is also essential QA to PA programs be conducted by highly trained and skilled individuals in order to receive the full benefit of any program.^{15,16,17,45,46,47} QA should be considered as essential ingredients in any school and learning rehabilitation curriculum. Most pre-pubescent children will benefit from qualitative based PE, whilst specific groups of children with learning, movement and/or behavioural problems will most likely receive the greatest benefit. Qualitative elements of PA are proposed to enhance and accelerate specific neural modulations and connectivity essential for optimal human cognition. This review aims to provide



foundations for health professionals and educationalists using physical movements for optimal physical, emotional and cognitive development in children. ●

Wayne Haynes D.C.D.O is a PhD student at Canberra university examining the relationship between postural stability and childhood development. Part of the PhD involves the examination of postural stability development, fine motor control and spatial awareness in the Lifestyle Of Our Kids (LOOK) study headed by professor Richard Telford. This study examines the developmental profile of 800 children beginning in year 2 in a longitudinal quasi experimental research format with a control and intervention group over 4 years. The intervention group received 4 years of specialised PE from Bluearth specialist coaches. Contact the Author: dchaynes@live.com.au

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Conflict of Interest

Wally Johnston has a role as an advisor to the "Essential Moves" program. No other conflict of interest is noted.

References available from AIMA: admin@aima.net.au

Bibliography

1. Katzmarzyk PT, Malina RM, Song TM. Physical activity and health-related fitness in youth: a multivariate analysis. *Med Sci Sports Exerc.* 1998;30(5):709-714.
2. Freedman DS, Dietz WH, Srinivasan SR. The relation of overweight to cardiovascular risk factors among children and adolescents: The Bogalusa Heart Study. *Pediatrics.* 1999;103:1175-1182.
3. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000-2003. *J Sci Med Sport.* 2004;7(1):S6-19.
4. Burgeson CR, Wechsler H, Brener ND, Young JC, Spain CG. Physical education and activity: Results from the School. Health Policies and Programs Study 2000. *Journal of School Health* 2001;71(7):279-293.
5. Strong W, Malina R, Blimkie C, et al. Evidence based physical activity for school-age youth. *J Pediatr.* 2005;146(6):732-737.
6. Tomporowski PD, Davis CL, Miller PH, Naglieri JA. Exercise and Children's Intelligence, Cognition, and Academic Achievement. *Educ Psychol Rev.* 2008;20:111-131.
7. Trudeau F, Shephard RJ. Physical education, school physical activity, school sports and academic performance. *Int J Behav Nutr Phys Act.* 2008;5(10):1479-1458.
8. Brisswalter J, Collardeau M, René A. Effects of Acute Physical Exercise Characteristics on Cognitive Performance. *Sportsmedicine.* 2002;9:555-556.
9. Haynes W, Kyte J. Physical Activity May Promote Optimal Academic and cognitive Potential in Children – Two Different Mechanisms are at work. Part One. Unpublished paper.

10. Haynes W, Kyte J. Physical Activity May Promote Optimal Academic and cognitive Potential in Children – Two Different Mechanisms are at work. Part Two. Unpublished paper.
11. Bailey RC, Olson J, Pepper SL, Porszasz J, Barstow TJ, Cooper DM. The level and tempo of children's physical activities: an observational study. *Med Sci Sports Exerc*, 1995;27:1033-1041
12. Raine A, Reynolds C, Venables PH, Mednick, SA. Stimulation seeking and intelligence: A prospective longitudinal study. *Journal of Personality and Social Psychology*. 2000;82:663-674.
13. Skoyles, JR. Human metabolic adaptations and prolonged expensive neurodevelopment: A review. 2008a. *Nature Preceedings*. <http://hdl.handle.net/10101/npre.2008.1856.1>
14. Skoyles JR. Respiratory, postural and spatio-kinetic motor stabilization, internal models, top-down timed motor coordination and expanded cerebello-cerebral circuitry: a review. 2008b. *Nature Proceedings*: doi:10.1038/npre.2008.2092.1. At <http://human-existence.com>
15. Blueearth foundation. Blueearth Approach. www.blueearth.org.au
16. Larke K. Essential Moves. 2005. www.essentialmoves.com.au
17. Pheloung B. School Floors. Movement to Learn. Hyde Park Press. 2006
18. Ceci SJ, Liker JK. A day at the races: a study of IQ, expertise, and cognitive complexity. *Journal of Experimental Psychology: General*. 1986;115:255-266.
19. Skoyles JR. Expertise vs general problem solving abilities in human evolution. *Psychology*. 1999a; 10(051).
20. Skoyles JR. Human evolution expanded brains to increase expertise capacity, not IQ. *Psychology*. 1999b;10(002) brain expertise (1).

21. Sternberg RJ. Intelligence as Developing Expertise. *Contemporary Educational Psychology*. 1999; 24: 359–375.
22. Darwin. Online Variorum of Darwin's "Origin of the Species": first British edition 1859. <http://darwin-online.org.uk>
23. Edelman GM. Neural Darwinism: Selection and Re-entrant Signalling in Higher Brain Function. *Neuron*. 1993;10:115-125.
24. Assaiante C, Mallau S, Viel S, Jover M, Schmitz C. Development of postural control in healthy children: A Functional Approach. *Neural Plast*. 2005;12(2-3):109-118.
25. Selles RW, Wagenaar RC, Smit TH, Wuisman PIJM. Disorders in trunk rotation during walking in patients with low back pain: A dynamical systems approach. *Clinical Biomechanics*. 2001;16:175-181.
26. Mouchnino L, Mesure S, Lizée E, Landjerit B, Massion J. Is the spinal column a rigid or articulated axis during leg movement? *Human movement science*. 1998;17:289-306.
27. Martell SG, Vickers JN. Gaze characteristics of elite and near-elite athletes in ice hockey defensive tactics. *Human Movement Science* 2004; 22:689–712.
28. Macefield G, Gandevia SC. The cortical drive to human respiratory muscles in the awake state assessed by premotor cerebral potentials. *The Journal of Physiology*. 1991;43:545-558.
29. MacLarnon A, Hewitt G. Increased breathing control: Another factor in the evolution of human language *Evolutionary Anthropology: Issues, News, and Reviews*. 2004;13(5):181-197.
30. Fuster JM. *The Prefrontal Cortex*. Elsevier. 4th edition. 2009.

31. Koziol LF, Budding DE. Subcortical Structures and cognition. Springer Science. 2010.
32. Ito M. Control of mental activities by internal model in the cerebellum, *Nature Reviews Neuroscience*. 2008;9:304–313.
33. Diamond A. Close Interrelationship of motor Development and Cognitive Development and of the Cerebellum and Pre Frontal cortex. *Child Development*. 2000;71(1):44-56.
34. Kandell E, Schwartz J, Jessel T. Principles of Neural Science. 4th ed. McGraw-Hill; 2000.
35. Ayres AJ. Sensory Integration and the Child. Western psychological services. 3rd edition. 2005.
36. Goddard-Blythe S. Attention, Balance and coordination. The A.B.C. of learning success. Wiley Blackell. 2009.
37. Schott JM, and Rossor MN. The grasp and other primitive reflexes. *Journal of Neurology, Neurosurgery and Psychiatry*. 2002;74:558-560.
38. McPhillips M, Sheehy N. Prevalence of Persistent Primary Reflexes and Motor Problems in Children with Reading Difficulties. *Dyslexia*. 2004;10:316–338.
39. Ansari D, Dhital B. Age-related Changes in the Activation of the Intraparietal Sulcus during Nonsymbolic Magnitude Processing: An Event-related Functional Magnetic Resonance Imaging Study. *Journal of Cognitive Neuroscience* 2006;11:1820-1828.
40. Mihara M, Miyai I, Hatakenaka M, Kubota K, Sakoda S. Role of the prefrontal cortex in human balance control. *NeuroImage*. 2008; 43:329–336.

41. Thompson R, Duncan J. NeuroImage. Attentional modulation of stimulus representation in human fronto-parietal cortex. Neuroimage. 2009 ; 48(2): 436-48.
42. Van Gog T, Paas F, Marcus N, Ayres P, Sweller J. The Mirror Neuron System and Observational Learning: Implications for the Effectiveness of Dynamic Visualizations Educ Psychol Rev. 2009;21:21–30.
43. Woollacott M, Shumway-Cook M. Review Article. Attention and the control of posture and gait: a review of an emerging area of research. Gait Posture. 2002;16(1):1–14.
44. Christakou A, Halari R, Smith A, Ifkovits E, Brammer B, Rubia K. Sex-dependent age modulation of frontostriatal and temporo-parietal activation during cognitive control. NeuroImage. 2009;48(1):223-236.
45. Move to Learn website. www.movetolearn.com.au
46. Gymbaroo early infant physical activity programs. www.gymbaroo.com.au
47. Extra lesson early intervention program <http://www.extralesson.com/index.html>
48. Learning Connections website www.learningconnections.com.au

Appendix

box 1. Summary of selected papers exploring Qualitative PA and cognition follow links at www.aima.net.au

Brown B. The effect of an isometric strength program on the intellectual and social development of trainable retarded males. *American Corrective Therapy Journal*. 1967;31:44-48. **POSTURAL STABILITY (PS) WITH ATTENTIONAL FOCUS. 40 12-year old boys with low IQ (Mean IQ=35).** Children randomly placed to either a 6-week exercise isometric program (12 yoga-like activities) or an attention-control condition. Children who participated in a yoga exercise program, compared to controls improved on both the IQ test (exercise ES=0.54; control ES=0.13) and the social scale (exercise ES=0.86; non-exercise ES=0.08). Brown hypothesized that "Because the exercise tasks required the children to attend, use memory and reasoning processes, and control motor movements exercise-related improvements were due to the mental demands experienced by children."

Buddea H, Voelcker-Rehageb C, Pietraßyk-Kendziorraa S, Ribeiroc P. Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters*. 2008;441:219-223. **COORDINATION CONCENTRATION ATTENTION IN HIGH ACADEMIC ACHIEVERS (gifted kids).** 115 adolescents 13-16yrs. Intervention daily coordination exercises (CE). CE more effective in completing the concentration and attention task compared to controls. "Because of neuronal connections between the cerebellum and the frontal cortex, bilateral CE may effect cognition!" "CE might lead to a pre-activation of parts of the brain which are also responsible for mediating functions like attention."

Knight D, Rizzuto T. The Relations for Children in Grades 2, 3 and 4 Between Balance Skills and Academic Achievement. *Perceptual and Motor Skills*. 1993;76:1296-1298. **RELATIONS FOR CHILDREN IN GRADES 2, 3, AND 4 BETWEEN PS AND ACADEMIC ACHIEVEMENT.** 122 7-11 year olds. 10 dynamic or static postural tests were judged pass/fail and score given out of 10. High correlation between high balance scores and success in numeracy and reading in data suggest the reading and mathematics academic achievement scores increase as several balance skill scores increase.

Reynolds D, Nicolson R, Hambly H. Evaluation of an Exercise-based Treatment for Children with Reading Difficulties. *Dyslexia*. 2003;9:48-71. **QUALITATIVE PA PROGRAMS' INFLUENCE ON AS IN DYSLEXIA.** Evaluation of an Exercise-based Treatment for Children with Reading Difficulties (Dyslexia). Halsam school project provided statistically significant improvements in reading, reading comprehension and numeracy. Program provided training in postural stability, movement coordination and visual attention to task.

Vieiraa S, Quercia P, Michela C, Pozzo T, Bonnetblanca F. Cognitive demands impair postural control in developmental dyslexia: A negative effect that can be compensated. *Neurosci Lett*. 2009;462(2):125-129. **Cognitive demands impair postural control in developmental dyslexia: A negative effect that can be compensated.** Dyslexic children show cerebellar signs, such as motor coordination impairment, reach and gaze overshoot or unbalance, inaccurate ocular proprioception. The link between PS deficits and dyslexia opens the possibility to improve PS and reading abilities. Treatment included postural advice, PS training, breathing exercises and application of prism glasses Possible to recalibrate the relationship between cognitive demands and PS in dyslexic children. **Cognitive demands and balance control are linked and interact in developmental dyslexia. Significant improvement in reading scores in intervention group**

Tsai CL. The effectiveness of exercise intervention on inhibitory control in children with developmental coordination disorder: using a visuospatial attention paradigm as a model. *Res Dev Disabil*. 2009;30(6):1268-80. Epub 2009 Jun 3. **TABLE TENNIS AS A QUALITATIVE PA INTERVENTION FOR ENHANCED COGNITION.** Table tennis promotes eye hand co-ordination, attention, focus, strategy formation and PS under low to moderate PA intensity load. Examined the effect on attentional networks in 43 9-10 year olds with DCD. Intervention and control. M-ABC and cognitive control task. **Table-tennis training resulted insignificant improvement of cognitive and motor functions for the children with DCD.**

Rothlisberger M, Michel E. Development and evaluation of motor coordination training for children in special-needs classes *Prax Kinderpsychol Kinderpsychiatr*. 2009;58(3):215-30. Medline abstract. (German Publication). **QUALITATIVE PA TRAINING IN SPECIAL NEEDS CHILDREN AND THE COGNITIVE INFLUENCE.** Special need children perform systematically poorer in executive functions and motor coordination skills compared to non-selected controls. Qualitative PA included body coordination, rhythm and balance with flexibility of action, interference control and focused attention. Training - easy to complex, action accuracy to speed, teacher guidance to children's self monitoring. 3 weeks duration. 53 children were trained daily for 20 mins. "children in the training condition caught up during training in specific cognitive and motor tasks, and trained children showed a more optimistic self-concept. Training effects were pronounced for children with balance problems."

Niklasson M, Niklasson I, Norlander T. Sensorimotor therapy: using stereotypic movements and vestibular stimulation to increase sensorimotor proficiency of children with attentional and motor difficulties. *Percept Mot Skills*. 2009;108(3):643-69. **PRE-ADOLESCENT BALANCE TRAINING IMPROVES SENSORY MOTOR PROFILE IN LEARNING DISORDER, DCD, ADHD** sensorimotor therapy Retraining for PS. 232 children (181 boys, 51 girls), whose mean age was 9.3 yr. (SD = 2.7), presented attentional and motor difficulties. Treatment period 3 years. Study authors suggested PS training may prove a viable treatment for children with Developmental Coordination Disorder, Learning Disability, and ADHD. Study included as authors suggested possible relationship with cognitive function and balance training.

Box 1. Summary of selected papers exploring Qualitative PA and cognition