CYCLIC CORTICAL REORGANIZATION, PHASE RESET AND THE DEVELOPMENT OF COGNITION

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A summary and integration of 38 years of EEG and neurophysiological studies of brain development will be presented. It will be argued that brain development does not cease at birth. Instead, postnatal brain development is a continuation of embryonic cyclic gradients along the anterior-posterior and medial-lateral axes. The cycles are very fast on the order of hours in the first trimester that then slow to months and years during postnatal development and over the human lifespan. A model will be presented of cycles of postnatal development that are characterized by periodic over production of synaptic connections followed by pruning of synapses in a spatio-temporal pattern (Thatcher, 1992a; 1992b; 1994; Thatcher et al. 1987; 2007; 2008a). Cycles of spatial-temporal gradients of synaptic development can be modeled by the biology of competition, cooperation, independence and predatory/prey nonlinear dynamics (Thatcher, 1998). Stages of development reflect the outward manifestation of an underlying cyclic dynamic producing hierarchical organization and increased efficiency and complexity that reaches periods of stability (plateaus and stages). The underlying dynamic is driven by brain stem and thalamic rhythm generators and the EEG can be modeled as a system of nonlinear thalamo-cortical pacemakers measured by rapid phase shifts of about 30 to 100 msec followed by phase locking of about 100 msec to > 1,000 msec (Thatcher et al, 2008a; 2008b). The sequence of phase shift (e.g., 50 msec) followed by phase lock (e.g., 300 msec) represents a process by which neural resources are recruited at each instant of time by a phase shift followed by phase locking to a function for an extended period of time as a spatio-temporal clustering of momentarily synchronized groups of neurons (coherence is positively correlated to phase lock duration). The time course of neural clusters will be presented and the development of phase shift and phase locking will be shown (Thatcher et al, 2008a). The development of phase shift and phase lock duration shows that on a global level the development of EEG phase reset exhibits ultra-slow oscillations and growth spurts from birth to 16 years of age. On the micro level there are growth spurts superimposed on a steady increased connectivity in local networks and a selective pruning of long distance connections. A «small-world» model of developmental complexity is an inverted 'U' shaped function with integration and differentiation on the x and y axes. Optimal complexity is at the apex of differentiation and integration. The maturation of cognitive abilities occurs in growth spurts that are represented as a trajectory on an inverted 'U' shaped model of complexity and increased efficiency.

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PREFRONTAL CORTEX AND DEVELOPMENTAL PSYCHOLOGY: STRATEGIES THAT WORK FOR IMPROVING COGNITIVE CONTROL AND SELF-REGULATION IN YOUNG CHILDREN

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Executive function (EF) skills are critical for success in school and life. Many children begin school lacking needed EF skills, especially lower-income children.

Educational practices that improve EFs lead to better academic outcomes and may head off mental health problems (such as ADHD) from developing. Many issues are not simply education issues or health issues; they are both.

EFs are, of course, brain-based, but they are not immutable. Evidence will be presented that they can be improved even in children as young 4–5 years of age, in regular public-school classrooms, with regular teachers, without specialists or special equipment. Many interventions address fixing problems after they have arisen; working with young children to prevent problems from arising may lead to far better outcomes at much less expense.

For example, an innovative Vygotsky-based early education program *Tools of the Mind*, improves EFs by (a) embedding supports for, training in, and challenges to, EF in all school activities and (c) emphasizing social pretend play (remember what you planned and follow through, hold in mind your role and those of others, inhibit acting out of character, and flexibly adjust as your friends take the play scenario in unanticipated directions). Social pretend play thus exercises all three core EFs (working memory, inhibitory control, and cognitive flexibility).