
Experience-based Brain Development: Scientific Underpinnings of the Importance of Early Child Development in a Global World

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The evolution of the human species over the past 200,000 years led to the Agricultural Revolution 10,000 years ago, the beginning of our experiments in civilizations, and an increasing capability to innovate, communicate with others, and create, in many regions, reasonably stable, prosperous, and democratic societies. Today we face the challenges of population growth, aging societies, population migration, climate change, and constraints on resources (energy, water, and food) necessary to sustain life. In the past when societies could not meet the challenges to sustain prosperous, healthy societies, the civilizations tended to regress or collapse.

Today more than in any other period in our existence, we have a better understanding of factors that influence the health, well-being, and competence of populations and the stability of civilizations. If we are to meet the challenges of the 21st century, it is crucial that we make the investments now to establish the next generation of healthy, competent populations in all regions of the world.

We now understand, better than ever before, how *experience-based* brain and biological development in the early years (i.e., conception to age 6 years)—

- Sets basic competence and behavior of individuals in respect to how they cope and contribute to the society in which they live and work
- Differentiates sensory nerve-cell functions in the brain (vision, sound, touch, etc.)
- Influences development of the neural pathways from the sensory nerves to other parts of the brain involved in emotions, response to stress, physical movement, language, cognition, and biological pathways that affect health and well-being.

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There are critical and sensitive periods in early life when the differentiation of nerve function and establishment of neural pathways occur. There are sensitive periods in the early years in which the neural pathways that are important in brain function connecting the different parts of the brain and the body develop. This explains why the early years of experience and brain and biological development can set trajectories in health (physical and mental), behavior, and learning that last throughout the life cycle. It is difficult to change many of these neurological pathways in the later stages of life.

In view of this new evidence concerning factors that affect brain development and influence the health, well-being, and competence of populations, why is there such a gap between *what we know* and *what we do*? For our present experiments in civilization to succeed, we have no choice but to increase the quality of our investment in early child development to establish healthy, competent populations.

This is a crucial challenge for the human species as we attempt to establish prosperous, healthy, tolerant, peaceful, stable, and democratic societies in a complex changing world. Unless we find strategies to improve early child development in all societies, we risk slipping into chaos—with negative effects on future populations.

Early Child Development, Population Health, and Well-being: Historical Perspectives

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Early Child Development, Population Health, and Well-being: Historical Perspectives

Historically, enhanced early child development in societies has led to the improved health and well-being of populations and prosperous, democratic societies. The Industrial Revolution of the 18th century is an example of this social change.

The Industrial Revolution and Improved Early Child Development

Analysis of the social and economic history of Western countries over the past 250 years shows that countries, such as Great Britain, became more prosperous after the start of the Industrial Revolution. This greater prosperity was associated with improved standards of living, social changes, increasingly democratic societies, and improved health.

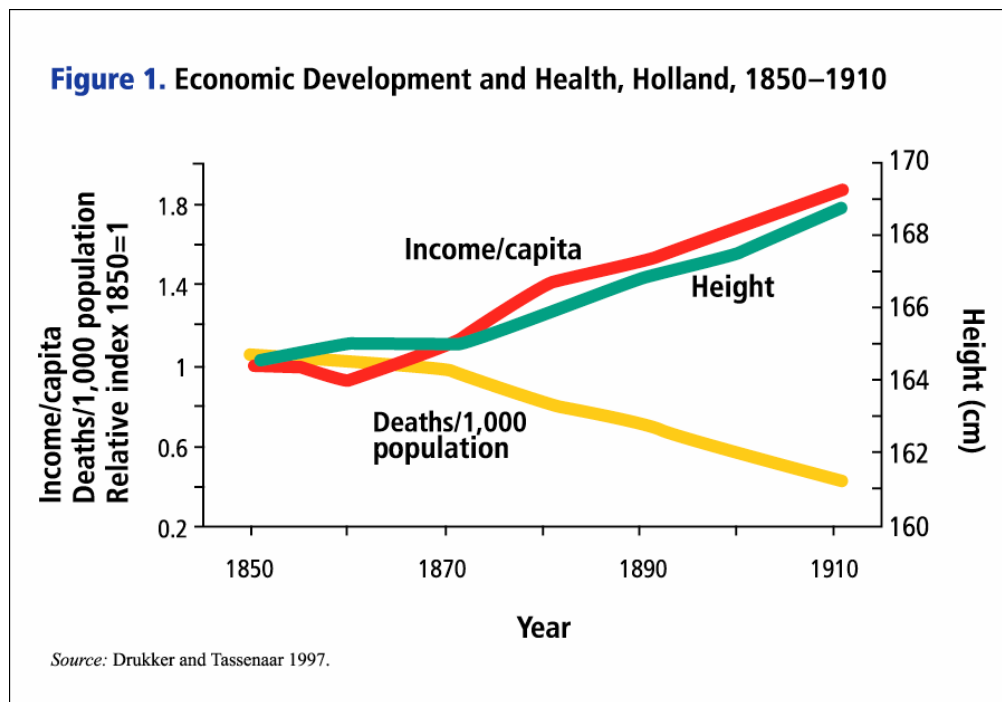
McKeown (1976), by a process of exclusion in his research, attributed the improved health (reduced mortality rate) of the British population during this period mainly to better nutrition. He concluded that only about 25 percent of the decline in mortality was due to better sanitation, clean water, and medical interventions.

Fogel (1994, 2000), a Nobel laureate in economics, examined the effect of changes in the socioeconomic environment associated with the Industrial Revolution on health. Using data from several Western countries, he found that as the mean height of populations increased, the mortality rates declined. Since height results from genetic factors and nutrition in the early years, Fogel concluded that the improved health of Western populations during the Industrial Revolution was due in part to improved conditions of early childhood.

Data from Holland during 1850–1910 show similar patterns. As Holland became more prosperous, the mean height of the population increased and mortality rates declined (figure 1). This evidence is compatible with the hypothesis that the early years of life set risks for health problems in adult life.

The increased prosperity also was associated with a decline in fertility rates, an increase in child spacing, and a decrease in the number of children in families—changes that would have reduced young children’s risks of infection and poor growth and development. In Western countries, the improved socioeconomic environment (including better nutrition) associated with the Industrial Revolution had beneficial effects on child development.

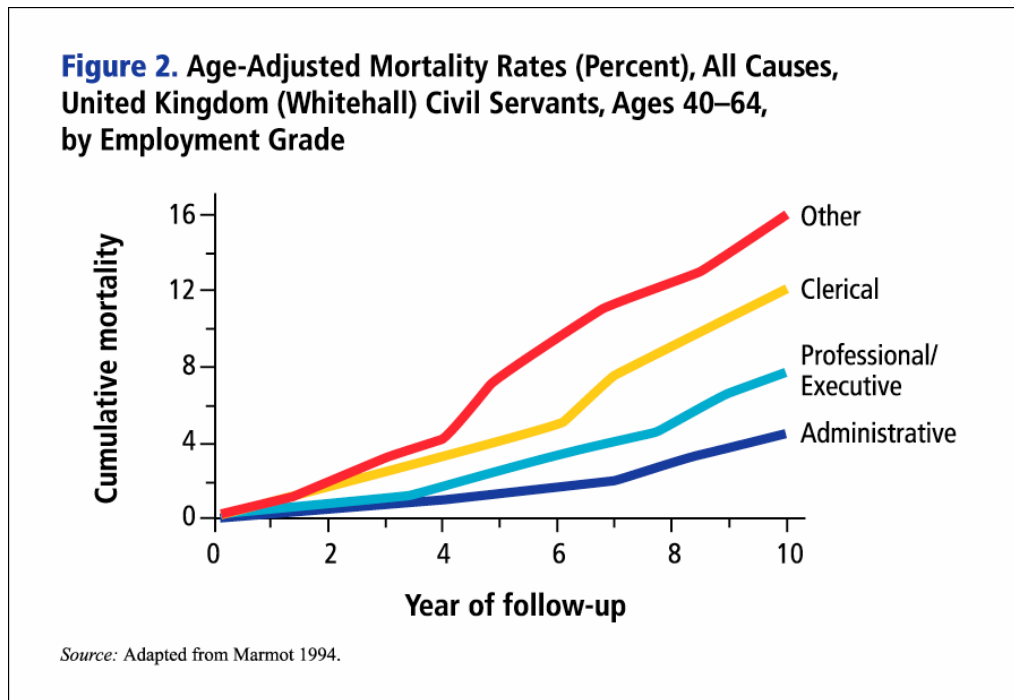
Recently, it has been shown that health and well-being of populations in different societies are a gradient when mortality data are plotted against the socioeconomic position of individuals in the population.



Health and Socioeconomic Gradients

By tracking the relationship between health and socioeconomic circumstances from established databases in Western society, researchers have shown that there is a relationship between the socioeconomic position of individuals in society and their health and well-being, at least for industrialized countries in the 20th century. This relationship has been termed a *socioeconomic gradient in health*.

Figure 2, as an example, depicts the socioeconomic gradient in mortality for men in the United Kingdom civil service. This is a middle-class population not living in poverty.



The relationship between position in the socioeconomic structure of society and health is a linear gradient. It is not simply a question of poverty (low income), but rather of an individual's position in the socioeconomic hierarchy. In 1998, Donald Acheson chaired a committee that reported to the British government on the determinants of inequalities in health in the United Kingdom (Acheson 1998) as seen from the health gradient studies and other studies. The committee concluded, based on the available evidence—

There is no doubt that early child development has a long reach that affects physical and mental health and well-being in the later stages of life.

Since early childhood development appears to be a factor contributing to these gradients, and they are not disease specific, further exploration has led to recognition that the development of the brain and biological pathways in early life is a key factor in causing these health gradients seen in adult life.

Since brain development in the early years is a factor in the gradients in the health status of populations, studies by a number of investigators have now shown that other functions of the brain in the early years of development, such as language, literacy, cognition, and behavior, are also gradients when plotted against the socioeconomic position of individuals in society (Keating and Hertzman 1999).

The evidence reinforces the idea that the development of the brain in the early years is a key factor affecting risks for physical and mental health problems and learning in adult life.

Experienced-based Brain and Biological Development during Early Childhood

The new knowledge from research in the neurosciences and biological sciences is providing evidence of *how* the social environment “gets under the skin” to affect the gradients in health, learning, and behavior. Experience-based brain development in utero and during the early years of life can *set* brain and biological pathways that affect an individual’s health, behavior, and learning for a lifetime.

The brain is composed of billions of neurons, all of which have the same genetic coding. There has to be, during the early stage of development, biological processes that differentiate the function of neurons that respond to the sensing pathways. As the brain develops during the early years, specific genes are activated in different parts of the brain to establish neurons that can respond to the signals coming from outside the body by the sensing pathways (such as vision, hearing, smell, touch).

The stimuli (experience) from the sensing pathways to which the sensing neurons are exposed during critical, sensitive early periods of development (including in utero) *set* most of the brain’s capability to interpret the signals and pathways in the brain which govern or control language, intellectual, emotional, psychological, and physical responses.

Genes can be activated and deactivated by processes (methylation and acetylation) that affect the function of the normal gene or the histone proteins around which the gene coils. This process is referred to as *epigenetics*. There is evidence from animal experiments that experience can influence the epigenetic process. The effects are stable and persist into adulthood. When a cell that has genes which have been affected by epigenetics replicates, the epigenetic effect is replicated with it.

This biology—of neuron differentiation, synapses, and epigenetics—has major ramifications for understanding how individuals with the same gene structure can have different phenotypes.

The Sensing Pathways: Vision, Sound, and Touch

The development of sensing pathways—vision, sound, and touch—occurs at critical periods in early development and is difficult, if not impossible, to remediate later.

Vision

Studies of the development of the neurons in the occipital cortex, the part of the brain responsible for vision, have helped scientists to understand the biological mechanisms by which experience affects the differentiation and function of neurons to process the signals from the retina of the eye. In animal experiments, Hubel and Wiesel (1965) established that, if signals do not pass from the retina to the occipital cortex of the brain during a critical period in early life, neurons will not develop the normal functions for vision.

Extensive experiments conducted since Hubel and Wiesel’s major finding indicate that there is a critical period for development and wiring of the brain for vision—which can be triggered

once, but only once. This research has led scientists to conceive of *critical periods for brain development*—at least for some sensing systems, such as vision, hearing, and possibly touch.

Sound

The development of individuals' auditory pathway also appears to have a similar critical period. For example, children born with a dysfunctional cochlear system in the ear are deaf. If this defect is corrected by surgically implanting a cochlear device, there is some restoration of hearing. If the surgery is performed too late, there will be no, or limited, restoration of hearing.

Touch

This sensing pathway also appears to have a critical or sensitive period for development. This pathway affects a number of different neurological and biological pathways. Touch has a very significant effect on development of the limbic-hypothalamic-pituitary-adrenal gland (LHPA) axis, or stress pathway.

Scientists' understanding of the development of the sensing pathways has led to considerable interest in the *plasticity* of neurons and neuronal pathways throughout life and in the concept of *critical and sensitive periods* during the early development of the sensory pathways.

Wiring and Sculpting of Neuronal Pathways

The neurons in the brain that translate the signals that come from the sensing pathways have to interact with the other pathways in the brain that affect emotion, behavior, language and literacy, speech, cognition, and the biological pathways that affect physical and mental health. These neural pathways influence how we cope with the everyday challenges of life. They have sensitive periods for development, but are more plastic than the primary sensing pathways.

The LHPA, or stress, pathway is a critical pathway that is affected by stimuli sensed through the sensing pathways. This pathway is connected to a number of circuits in the brain. It responds to the daily experience of individuals, and it relates to emotion, fear, and response to threats. It influences, for example, cardiovascular function, behavior, cognition, and immune function.

We now have a better understanding about how the pathways develop in respect to language and literacy. The development of these different brain pathways can be thought of as a hierarchy in development. Pathways that develop early may be difficult to change in later stages of development, whereas those that develop later may be more plastic in terms of changing their function. It is generally accepted that there is a reduction in the plasticity of these circuits after a sensitive period has ended.

There are parts of the brain that are capable of continuing renewal and development in normal circumstances. One region of the brain that has been extensively studied in respect to renewal is the hippocampus, which is important in respect to memory.

In a detailed analysis of neurons and their connections, it was found that, at birth, the axons, dendrites, and synapses in the brain are not extensive, but at the age of 6 years, the neuron connections and synapses are extensive. By age 14 years, the synapses are less extensive.

The connections between neurons are strongly influenced by stimulation. Hebb (1949) referred to this process of the wiring and sculpting of the brain as “neurons that fire together, wire together.” The formation of long-lasting synaptic connections is dependent upon the frequency of the stimulation of the receiving neuron. Frequent stimulation leads to activation of genetic pathways in the brain which produce proteins that strengthen synapses.

The LHPA (Stress) Pathway

The LHPA pathway has major effects on physical and mental health. In discussing the stress response, two terms are often used—the limbic system, and the hypothalamus-pituitary-adrenal (HPA) pathway or axis.

The term limbic system was originally used to relate to the center for emotions. Since the concept was introduced, there is evidence that two structures in the limbic system of the brain (hippocampus and amygdala) play important roles in emotion, behavior, and memory and are inseparable from the stress response. The stress pathway is considered by many to involve the limbic system and includes the amygdala, the hypothalamus, the pituitary gland, the adrenal gland, and the hippocampus. The stress pathway also involves the autonomic nervous system.

One set of nerves projecting from the amygdala reaches parts of the mid-brain and brainstem which control the autonomic nervous system. It is this pathway that stimulates the autonomic nervous system to release epinephrine, which has a quick action and, among other actions, increases the heart rate, affects breathing, and enhances senses. The activity reflects a form of implicit memory in that it does not require a conscious awareness.

The hormones released by stressful stimuli work at different speeds. Epinephrine (adrenaline) works quickly, whereas the action of cortisol (a glucocorticoid) is slower. The amygdala plays a major role in the response to stress through the autonomic nervous system (epinephrine) and the cortico-releasing hormone pathways.

The hypothalamus stimulates the pituitary gland to produce adrenocorticotrophic hormone (ACTH), which stimulates the adrenal gland to produce cortisol. The slower-acting HPA stress pathway leads to the release of cortisol, which affects the function of cells in different parts of the body, including the brain, and has a longer-lasting effect than epinephrine.

Cortisol can affect gene activation in different organs, including the brain. Through these pathways, cortisol affects metabolic pathways and vulnerability to health problems such as type II diabetes and coronary artery disease. Cortisol has major effects on cognition and memory through its action on receptors in the brain, particularly the hippocampus. Increased cortisol levels in the blood interact with receptors in the hypothalamus and hippocampus to shut down the stimulus (cortico-releasing hormone) from the hypothalamus.

In this dynamic system, emotional stimuli to the amygdala can override the normal regulation of the pathway, leading to continuous stimulus for cortisol production from the adrenal gland. This system can be thought of as similar to a thermostat in that its operation normally maintains an appropriate balance.

McEwen (2002) and others have shown that normal cortisol levels increase when you get up in the morning and return to low levels at the end of the day if it has not been too stressful and the LHPA pathway functions normally. McEwen describes this dynamic regulation as the maintenance of stability through change, and he refers to this process as allostasis. If the pathway does not return to a normal balance, this can be considered as increasing the allostatic load.

The capacity of animals to make allostatic adjustments through change is necessary for survival. If they persist too long, the excess cortisol can be damaging to the biological pathways influencing brain function and physical and mental health.

In studies of stress and development in rats, investigators have concluded that mothers' care during infancy programs stress responses in their offspring by modifying the neural systems in the LHPA axis. The findings from research in animals indicate that early rearing conditions can permanently alter the set point for the control of the LHPA system. This influences the expression of endocrine and biological responses to stress throughout life.

This work has provided evidence about how early life events can affect the function of the LHPA system and subsequent behavioral and mood disorders, as well as atherosclerosis and arterial thrombosis in animals. In their work, these investigators and others have concluded that conditions in early life can permanently alter gene expression (the epigenetic effect).

The investigators have found that adverse maternal behavior can lead to poor protein synthesis from DNA because of epigenetic effects on the gene promoter functions. Since methylation (an epigenetic pathway) of gene structures is difficult to reverse, this is a possible mechanism for the long-term environmental effects of maternal interaction with newborns on gene expression that can last throughout life.

The production of cortisol is important in how individuals cope with the daily demands of what they do. Overproduction of cortisol can influence behavior and health, such as antisocial behavior, depression, type II diabetes, cardiovascular diseases, memory, the immune system, and risk of drug and alcohol addiction. Underproduction is associated with chronic fatigue syndrome, fibromyalgia, autoimmune disorders, rheumatoid arthritis, allergy, and asthma.

Immune System

Another biological pathway that is influenced by the brain and the LHPA pathway is the immune system. In her recent book, Sternberg (2000) has outlined this pathway as follows—

New molecular and pharmacological tools have made it possible for us to identify the intricate network that exists between the immune system and the brain [particularly the stress pathway], a network that allows the two systems to signal each other continuously and rapidly. Chemicals produced by immune cells signal the brain, and the brain in turn sends chemical signals to restrain the immune system....Disruption of this communication network in any way, whether inherited or through drugs, toxic substances or surgery, exacerbates the diseases that these systems guard against: infectious, inflammatory, autoimmune, and associated mood disorders.

Cortisol has [from the stress pathway] a double-edged effect on the immune system. Too much of it suppresses immune function and makes us more vulnerable to infections. Yet in the short term, a burst of cortisol helps the immune system respond to an infection or injury. It sends the white blood cells, the body's main line of defense against injury and infection, to their battle stations....Cortisol also signals when the level of immune activity is adequate. It sends this message via the brain, which relays the information through the hypothalamus to the pituitary gland; the stress response is then adjusted accordingly. Cortisol's checks-and-balances effect is what makes it such a

successful treatment for problems resulting from a hyperactive immune system, such as rashes or allergies, and for autoimmune conditions in which the immune system attacks the body's own healthy tissue. When we put cortisone cream on a rash or take steroids orally to fight inflammation, we are only supplementing what our own cortisol normally does.

Cytokines from the body's immune system can send signals to the brain in several ways. Ordinarily, a "blood-brain barrier" shields the central nervous system from potentially dangerous molecules in the bloodstream. During inflammation or illness, however, this barrier becomes more permeable, and cytokines may be carried across into the brain with nutrients from the blood. Some cytokines, on the other hand, readily pass through leaky areas in the blood-brain barrier at any time. But cytokines do not have to cross the blood-brain barrier to exert their effects. Cytokines can attach to their receptors in the lining of blood vessels in the brain and stimulate the release of secondary chemical signals in the brain tissue around the blood vessels.

Cytokines can also signal the brain and affect nerve pathways, such as the vagus nerve, which innervates the heart, stomach, small intestine, and other organs of the abdominal cavity. Sternberg (2000) makes the point that the brain-body connections are crucial in the function of the immune system and the body's host defenses. This may be one of the reasons why quality stimulation of brain development in the early years is associated with better health in adult life.

In studies with rhesus monkeys, it was found that prolonged early social deprivation had an effect on mortality and a lifelong effect on cell-mediated immunity (Lewis and others 2000).

The Nature–Nurture Debate

The nature–nurture debate has, until recently, led to a strong view that the major factor in human brain development was primarily genetically driven regardless of experience. Today we know that although genetics are important, experience and the environment in which individuals exist from the in utero period through to adult life have a significant effect on gene activation and expression (Meaney and Szyf 2005).

It is clear that in the early period of development when the biological systems for vision, sound, touch, and other sensing pathways are developing, there has to be activation of genes in neurons to establish differentiation of neuron function. In terms of connections between neurons, there has to be repeated gene activation to form more permanent synaptic connections.

Kandel (2001) has described this gene story for memory as "the molecular biology of memory storage: a dialogue between genes and synapses." It is clear that the formation of long-term memory involves experiences and gene expression.

Gene activation, differentiation of neuron function, and synapse formation in the early years provide an explanation for some of the major behavioral problems we face in society.

It has been recognized in monkeys that if they are heterozygous for the short serotonin transporter gene-linked polymorphic region, they are at risk for decreased serotonergic function (serotonin is an important monoamine that influences, among other functions, the prefrontal brain and behavior). If the infant animals with the short gene structure are separated from their mothers when they are young (thereby lacking touch and other stimuli), they can develop poorly with abnormal LHPA pathways and poor serotonin function in respect to the prefrontal cortex and are at risk of abnormal brain function (depression and alcohol addiction). The animals homozygous for the long gene structure for the serotonin transporter gene are resistant to adverse experience in early infant development (these are resilient animals).

Recent studies of the 1970 Dunedin birth cohort have shown that children who were raised in an adverse abusive environment with one or two copies of the short allele of the serotonin gene promoter polymorphism were at risk for depression in adult life. Those with the short gene structure brought up in a good early child development environment were not at risk. The children in adverse environments who were most at risk were those with the two short alleles. Children who were homozygous for the long allele serotonin transporter gene structure were resistant to the adverse effects of poor early child development (these were resilient children).

Normally, gene abnormalities are thought to be caused by genes producing a defective protein. However, since the DNA of both the short and long genes is normal in terms of mRNA coding for the transporter protein, some other mechanism related to gene activation or inhibition (epigenetics) is involved. This is an example of how the social environment can “get under the skin” through the sensing pathways and influence biological pathways that can influence gene expression leading to behavior and mental health problems.

Another gene–environment interaction which is relevant for complex psychiatric and behavior disorders is the gene for monoamine oxidase A (MAOA). This enzyme oxidases the monoamine neurotransmitters serotonin, dopamine, and norepinephrine. Humans with low MAOA activity tend to be associated with impulsive behavior and conduct disorders. The MAOA gene, like the serotonin transporter gene, has a functional length polymorphism in the transcriptional control region for the gene.

A significant interaction between childhood maltreatment and low MAOA activity alleles has been found. This is associated with increased risk for antisocial behavior and violence. Individuals with high levels of MAOA expression did not show the same increase in conduct disorders as did those with low MAOA activity in relation to maltreatment in early childhood.

An important point that comes from this work is that it shows a nongenotype mechanism for transmitting patterns of behavior for genetically vulnerable animals to the next generation.

In the case of the serotonin transporter gene, a female with the short promoter gene structure who has suffered from poor early infant development will have behavior problems, such as depression, as a consequence of poor early development. She will then be at risk to poorly bring up her offspring, who could have a similar gene structure. These offspring will likely suffer from the same behavioral problems as the mother.

Lifelong Effects of Experience-based Brain Development

Beyond the biology of early child and brain development, behavioral, literacy, and population health research clearly shows that conditions of early childhood affect and set trajectories for health, behavior, and learning for children throughout life. The antecedents of adult health, behavior, and literacy—among other qualities—lie in early childhood. The evidence is substantial, as indicated below.

Early Child and Brain Development and Health

Conditions during pregnancy and early life influence the development of the brain and biological pathways that set risks for coronary heart disease, hypertension, type II diabetes, mental health problems, and other conditions in adult life, such as disorders of the immune system. The findings from a Swedish longitudinal study show that children brought up in poor environments (with neglect and abuse) during early child development have an increased risk in adult life for poor health.

In the Swedish study, the risk for cardiovascular problems for adults who had been in very adverse early child circumstances in comparison to those who were in good environments for child development was 7:1. The risk for mental health problems, such as depression, was 10:1. The data concerning depression in this study are compatible with what we are beginning to understand of how poor early child development can alter gene expression in relation to serotonin transport which can influence depression. The odds ratio for mortality for those brought up in the poorest environments was twice that of children brought up in good circumstances.

These observations are compatible with our increased understanding of how experience and brain development in the early years can affect pathways that affect emotions, behavior, and vulnerability to depression as well as coronary artery disease.

Studies using data from the United States from the National Health Interview Survey, the Panel Study of Income Dynamics, the Child Development Supplement, and the Third National Health and Nutrition Examination Survey have shown that the population health socioeconomic gradients in health can be detected early. Socioeconomic gradients in health could be detected by age 3 years, and the steepness of the gradients increased as the population became older.

This evidence is important since it shows that the gradient in health status in adults has its antecedent in early childhood. These findings are remarkably consistent with what we now know about the development of the brain in the early years and its effect on physical and mental health in later life.

A key conclusion is that if we wish to improve equity in health, investment from a public health perspective in the early years of life (prenatal and postnatal) is important. Also it is possible to spot signs and symptoms of poor early development and take steps to improve outcomes.

There have been a series of studies over the past 20 years showing that conditions in utero have a significant effect on physical and mental health problems throughout the life cycle. Investigators have concluded from these studies that men who grow slowly in utero remain biologically different from other men in adult life. They are more vulnerable to the effects of low socioeconomic status on the risk for coronary heart disease.

In a recent analysis looking at early development and health, studies were carried out on individuals in South Australia born between 1975 and 1976; men and women born in Preston, United Kingdom, from 1935 to 1943; and women born in East Hertfordshire, United Kingdom, from 1923 to 1930. The researchers concluded that low birthweight is associated with raised cortisol concentrations (which contributes to poor physical and mental health). Increased activity of the LHPA axis may be a factor in contributing to raised blood pressure in adult life. Because the association was observed in young men and women in Adelaide, Australia, as well as older populations in the United Kingdom, it could mean that the factors that lead to adult hypercortisolemia and the effects on health affect men and women in early adult life as well as later.

The in utero environment can influence risk for type II diabetes as well as behavior problems such as schizophrenia and possibly autism. In this work, investigators have concluded that the alteration in gene function by epigenetic processing will tend to stay with the individual throughout the life cycle.

A behavioral disorder that is of some significance in societies is attention-deficit hyperactivity disorder (ADHD), which affects 8–12 percent of children worldwide. Studies have shown that this condition in children can be associated with psychiatric and substance abuse disorders in later life. This appears to be a condition caused by the interaction between the environment, stimuli, and genetic vulnerability. Pregnancy and delivery complications, such as toxemia or eclampsia, prematurity and exposure to alcohol and cigarettes during pregnancy, appear to be environmental factors that can alter the brain development in vulnerable children in early life leading to this behavioral disorder.

Dysfunction of the LHPA axis with lower levels of cortico-releasing hormone secretion can, in part because of low plasma cortisol levels, result in a hyperactive immune system. Patients with a mood disorder called atypical depression also have a blunted stress response and impaired cortico-releasing hormone secretion, which leads to lethargy, fatigue, and increased eating that often results in weight gain. Patients with other illnesses characterized by lethargy and fatigue, such as chronic fatigue syndrome, fibromyalgia, and seasonal affective disorder (SAD), exhibit features of both depression and a hyperactive immune system associated with low cortisol levels.

There is also evidence from animal and human studies that poor development in the early years can lead to increased risk for alcohol or drug addiction. As discussed in the section on brain development, studies with rhesus macaque monkeys or rats show that inadequate touch stimulation in the early period of development influences the risk for both behavior and alcohol addiction problems in later life. In studies of the Kaiser Permanente program in California, it was found that individuals who had been exposed to child neglect and abuse when young were at high risk for drug and alcohol addiction in adult life.

In reviewing all of the available evidence about early childhood and health, Sir Donald Acheson's Commission on Inequalities in Health in Great Britain (Acheson 1998) concluded—

Follow up through life of successive samples of birth has pointed to the crucial influence of early life on subsequent mental and physical health and development.

Early Child and Brain Development and Behavior

In discussing this subject it is usual to separate psychiatric and nonpsychiatric behavior problems. An alternate way of looking at this is that because these various behavior disorders are in effect related to similar brain pathways, they may more be a product of different ways in which these brain pathways work and interact with each other. As discussed in the health section, how the brain develops in the early stages of life affects mental health problems later in life.

ADHD is a product of interaction between the environment and genetic vulnerability (Biederman and Faraone 2005). The brain pathways involved in ADHD are also involved in other (comorbid) forms of abnormal behavior. Among the comorbidity problems associated with ADHD are psychiatric disorders such as depression and substance abuse.

Although the reasons for this co-morbidity are not clear, it appears that the comorbidity is governed by environmental influences that affect shared neuron pathways. It is interesting that ADHD in early life is related to adults at risk for personality disorders at all ages. This behavior is associated with functional disorders such as school dysfunction, family conflict, poor occupational performance, and antisocial behavior.

It has been found that, at age 2 years, most children show a form of antisocial behavior (“the terrible 2s”) that usually comes under control before the children reach school age if the children are in good early child development environments. Children brought up in neglectful, abusive early child development conditions will show significant antisocial behavior at the time of entering the school system.

In a study of antisocial behavior (aggression) in children entering the Montreal school system, the investigators found that approximately 14 percent of children show little physical aggression and approximately 53 percent show moderate aggression that gradually comes under control. Approximately 32 percent showed high levels of aggression at the time of school entry with some improvement in control as they become teenagers.

Approximately 4 percent of the children did not improve and were considered chronic. Many of the teenage males in the chronic group ended up in the criminal justice system. In the study, only about 30 percent of children entering the school system with high or chronic antisocial behavior achieved a high school diploma. There is clearly an effect of the pathways affecting behavior on learning.

In studies of brain development and function in relation to neglect, physical or sexual abuse, and family violence, using today’s functional magnetic resonance imaging methods (fMRI) to study brain function, it was found that adverse early child development environments lead to changes in brain structure. The aftermath in adult life could appear as depression, anxiety, post-traumatic stress, aggression, impulsiveness, delinquency, hyperactivity, or substance abuse.

It has been proposed that the effects of early stress alter the neurological pathways in development that may prepare the adult brain to help individuals survive and reproduce in a dangerous and violent world.

An interesting longitudinal study of the relationship between early child development for language and intelligence in males was carried out in Sweden. Significant correlations were

found between registered teenage criminality and language (verbal skills) development at ages 6, 18, and 24 months.

Although there are many explanations for this relationship, it is difficult to ignore the evidence that the degree of verbal exposure to reading and talking in early development (infants, toddlers, young children) has a significant effect on individuals' verbal skills and language at later stages of development. Also it is difficult to talk to or read to infants or toddlers without holding them and stimulating sensing pathways such as touch and smell. As described in the section on brain development, touch is a critical factor influencing the development of the LHPA pathway, which, if it is dysfunctional, can influence behavior, including antisocial behavior, in later life.

Experiences (stimulation) of multiple sensing pathways in early life appear to affect multiple functions such as language, intelligence, and behavior in later stages of life.

This evidence is compatible with the concept that vulnerability in gene structure combined with a poor environment for early child development can lead to significant behavior and language problems in later life.

Early Child and Brain Development and Literacy

Language and literacy is a critical faculty for lifelong learning and achievement. In the modern technological world, adults who cannot read or who read, but have difficulty understanding are severely disadvantaged. Often they are in the lower echelon of occupations and may live at the margins of society, unable to compete and succeed in the marketplace. The globalization of economies may increase their vulnerability even more.

Brain development in the early years influences language and literacy. We know that the sounds that an infant is exposed to when very young influence how the auditory neurons develop and function.

For example, infants exposed to two languages (e.g., Japanese and English) in the first 7–8 months of life will have little difficulty in setting the base for easily mastering the two languages and will not have an accent when using these languages. Individuals who develop capability in two languages early in life have a larger left hemisphere of the brain than do individuals with monolingual backgrounds. Proficiency in the second language is directly related to the size of this part of the brain. Since acquisition of a second language is best achieved in very early life, this indicates that there is a sensitive period for brain development and function for optimum language acquisition, literacy, and the associated understanding.

It is interesting that the other findings from these studies are that individuals who acquire a second language very early in life find it easier to learn third and fourth languages later in life. It would appear that the neurons in the auditory cortex that respond to sound develop a sensitivity to the sounds of different languages in early life that make it easier to differentiate the sounds and develop the neurological pathways necessary for capability with multiple languages. Some investigators have concluded that the speech system remains most plastic to experience (sound) for a short period of time in early life.

Studies have shown the extent of a child's language exposure in the early years has a significant effect on the verbal skills of children by age 3 years. The difference in verbal skills at

age 3 years among different socioeconomic groups still held in respect to language capability and understanding at age 9 years.

This observation is compatible with the evidence that the most sensitive period for brain development in respect to language and literacy capability is in the early years. It has been shown that after the first years of life the ability to discriminate phonemes in languages to which children are exposed diminishes greatly.

Recent studies of children with dyslexia who have been through a program of language development based on phonemes indicate that there may be considerable plasticity in the neural circuits connecting the different parts of the brain involved in language and words. With this strategy, the brains of the dyslexic children (age 6 years or older) exposed to phonics programs established, as assessed by fMRI measurement, the development of normal neuronal pathways for both word reading and picture naming within 8 months. The children—as well as showing the normal activation of the centers for speech, reading, and language—no longer had difficulty in reading. These results indicate that many of the centers and neurological pathways for reading and speech are still, to some extent, plastic in later stages of development.

Population Literacy Levels

The Organization for Economic Cooperation and Development (OECD), Statistics Canada, and the U.S. Department of Education have conducted population-based assessments of literacy (prose, document, and quantitative) competence. The data are rather alarming, for they show that a significant proportion of the adult population (ages 16–65 years) in *both* industrialized and developing countries performs at low—and often the lowest—levels of literacy.

The population assessments reflect the level of individuals' performance in literacy on a scale of 1 (low) to 5 (high) (box 1).

Box 1. Literacy Performance Scale 1–5

Level 1: Individuals can answer questions from familiar contexts where all relevant information is present, questions clearly defined. Able to identify information, carry out routine procedures in explicit situations. Can perform obvious actions from the given stimuli.

Level 2: Individuals can interpret and recognize situations of direct inference. Can extract relevant information, employ basic procedures and are capable of direct reasoning. Can make literal interpretations of the results.

Level 3: Individuals can execute clearly described procedures, including sequential decisionmaking. Can select and apply simple problem-solving strategies. Can use representations based on different sources. Can develop short communications.

Level 4: Individuals can work with explicit models for complex concrete situations which involve making assumptions. Can select and integrate different representations with real world situations. Can utilize their well-developed reasoning skills to communicate explanations.

Level 5: Individuals can conceptualize and use information based on their investigations and models (advanced thinking and reasoning). Can apply insight to novel situations. Can formulate and precisely communicate their actions and reflections to the original situation.

The findings are as follows:

- In Canada and the United States, 42–52 percent of the adult population performs at levels 1 and 2 (low), and 18–23 percent performs at levels 4 and 5 (high).
- In Chile and Mexico, more than 80 percent of the populations perform at levels 1 and 2 (low), and only 3 percent or less perform at levels 4 and 5 (high).
- In other developing countries and areas (e.g., Africa), competence in literacy is even lower than it is in Latin America.
- In Sweden, by contrast, 23 percent of the population performs at levels 1 and 2 (low), and 34 percent performs at levels 4 and 5 (high).

Table 1 summarizes some of the findings.

Table 1. Document Literacy, Ages 16–65 Years, 1994–98

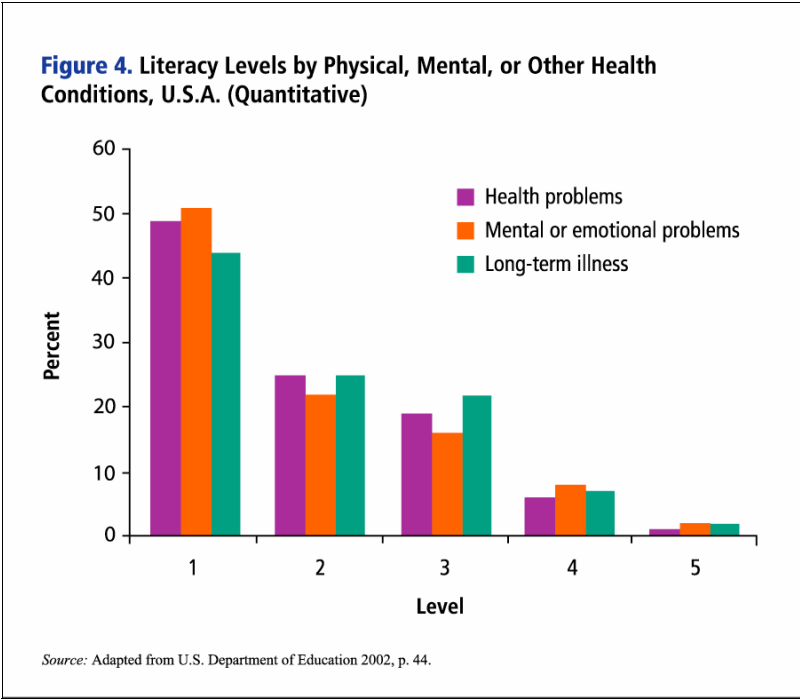
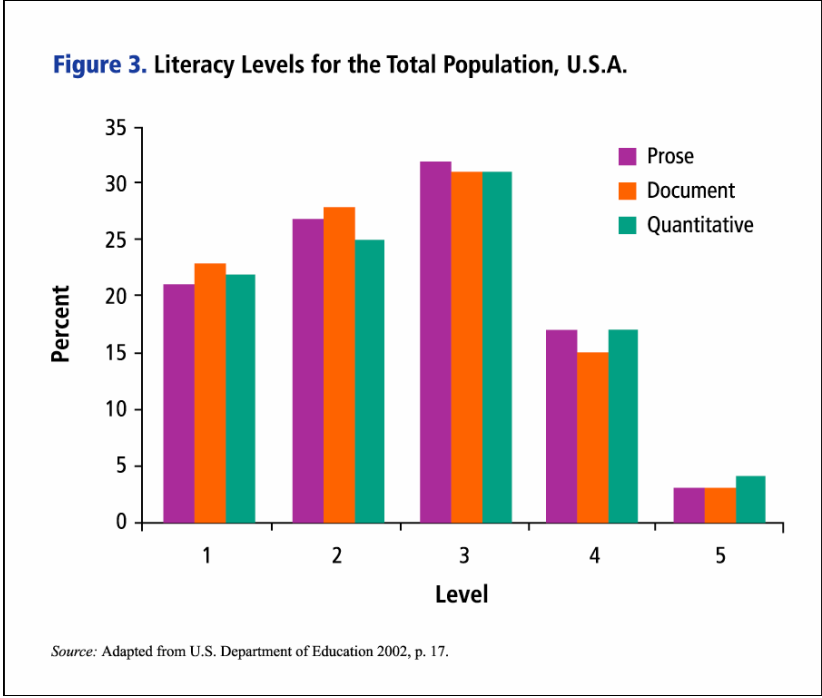
Country	Literacy level (percent)	
	Levels 1 and 2	Levels 4 and 5
Sweden	23	34
Canada	42	23
Australia	43	17
United States	48	18
Chile	85	3
Mexico	84	1.7

Source: All data except for Mexico are from OECD and Statistics Canada 2000. Mexico data are from OECD 2005.

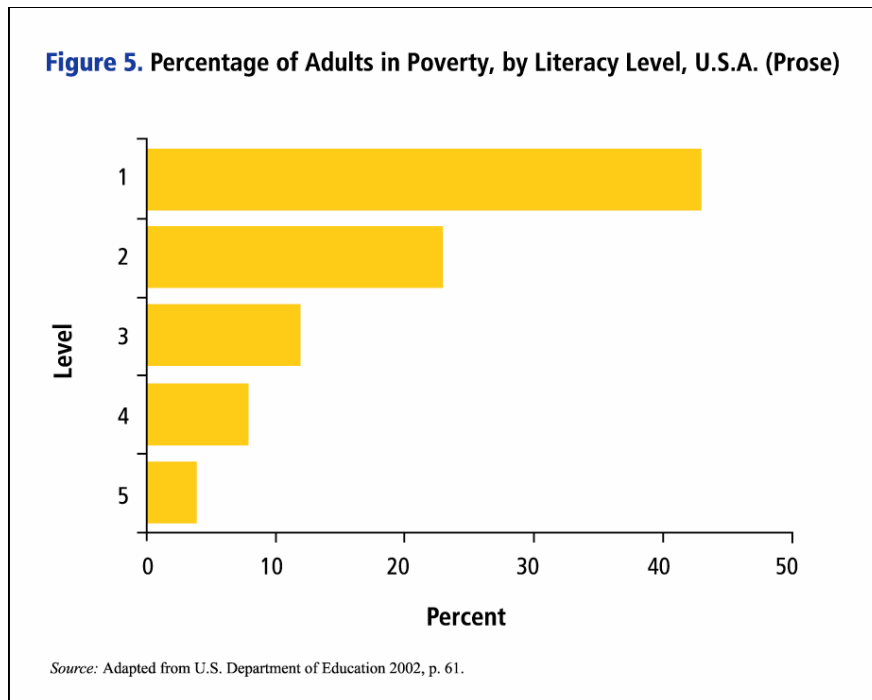
The generally low level of competence in literacy across the world is not adequate for individuals who want to—and need to—function satisfactorily in a globalized world that is undergoing exponential growth in new knowledge and technologies and facing complex socioeconomic conditions and changes in the environment. Low literacy is also related to lower life expectancy, poorer health, and poverty.

The U.S. Department of Education’s study of prose, document, and quantitative literacy has similar findings as do the OECD and Statistics Canada studies (figure 3). The figure shows that nearly 50 percent of the U.S. population is at levels 1 and 2 (low) and approximately 5 percent is at level 5 (high).

Health Problems. In the U.S. study, health problems are a gradient in relation to literacy competence. At each step down the scale of literacy capability, the health status of a population worsens. For example, approximately 50 percent of the U.S. population at literacy level 1 has physical and mental health problems, compared with less than 2 percent of the U.S. population at literacy level 5 (U.S. Department of Education 2002) (see figure 4).



Poverty. In industrialized countries, poverty also relates to literacy. For example, almost 45 percent of the U.S. population at literacy level 1 lives in poverty, compared with less than 5 percent of the population at literacy level 5 (U.S. Department of Education 2002) (see figure 5). As with health problems, the relationship between poverty and literacy in the U.S. population is a gradient.



These findings raise two interesting questions:

- Why does literacy competence relate to life expectancy, health, and poverty?
- How does experience-based brain development during early childhood effect the brain pathways that influence not only literacy, but also life expectancy, health, and income in adult life.

It could be argued that because Canada and the United States have a mixed immigrant population, in contrast with the more homogeneous Scandinavian population, the difference in literacy performance is due to the heterogeneity of populations in Canada and the United States. The study of Latin American countries conducted by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) (Casassus 1998), however, show that heterogeneity of populations is not a barrier to a country having a high literacy performance.

In particular, Cuba's performance in the literacy assessment for children in grades 3 and 4 is much better than that of the other Latin American countries (figure 6). The government of Cuba introduced health and other programs for mothers and young children more than 30 years ago. The focus was on health and child development. The key question that comes from these data is: Are the Cuban results different from those of Brazil, Chile, and Colombia because of the education, social-economic factors, or the investment in mothers and children?

Today, Cuba's performance in the literacy assessments is better than that of the other Latin American countries, and life expectancy is better than that in almost all other Latin American countries (table 2). Since we now know that literacy, competence, and life expectancy are related, it is not surprising that Cuba, a relatively poor Latin American country, but with excellent child development programs, has better life expectancy of most other Latin American countries.

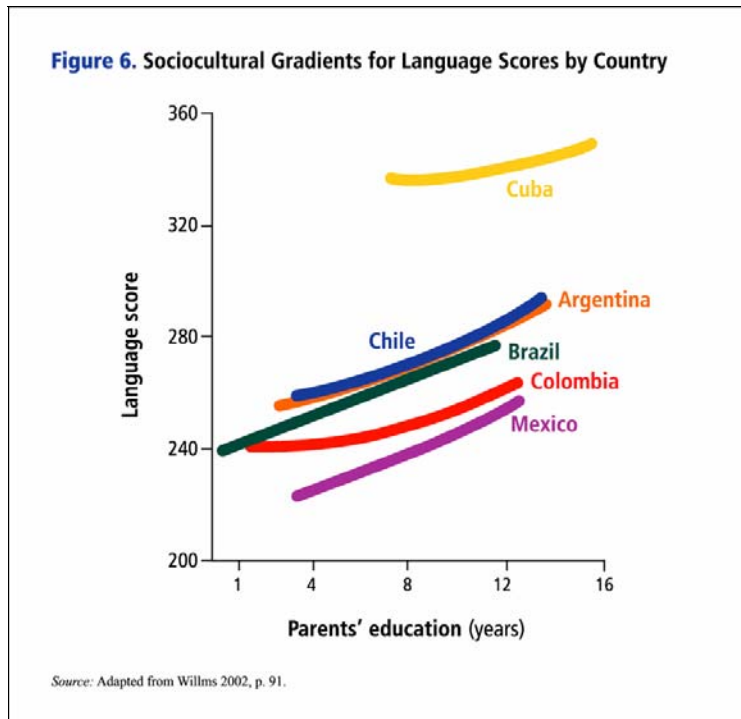


Table 2. Life Expectancy (Years) by Country

Country	Years
Argentina	74.1
Brazil	68.0
Chile	76.0
Cuba	76.7
Mexico	73.3

Source: Fukuda-Parr 2004.

In the UNESCO tests of language and mathematics, the mean value for Cubans was two standard deviations better than the mean value for other Latin American countries. Another interesting feature of the Cuban data is that Cuba had only one-fourth the number of fights in the school system in contrast with the data from the schools in the other Latin American countries.

The Cuban data are compatible with the concept that a good early child development (ECD) program can improve outcomes for a mixed population (African, Spanish, Indian). Cuba's ECD initiatives begin with pregnancy and continue until the children enter the school system. There are two components to the program:

- A center-based full-day program

- A community and home-visiting program which includes part-time community center-based initiatives.

The staff are well educated, and the programs are universal, but noncompulsory. More than 95 percent of the families with young children use these programs.

In all the population-based studies of health, behavior, and literacy, the outcome measures are a gradient when plotted against the socioeconomic status of the population studied. More than 75 percent of the Canadian population can be classified as middle class. In studies in Ontario and Canada, the greatest number of children showing poor development at the time of school entry was in the middle class. The most vulnerable are in the lowest social class.

Whatever in the social environment affects health, learning, and behavior, it affects all social classes. Thus, any program to improve the health, competence, and well-being of populations should be available for all families with young children.

Early Child Development Programs

Evidence from Early Child Development Interventions

Across the world, the United Nations, international agencies such as the World Bank and the Inter-American Development Bank, governments, and research groups have undertaken numerous studies of early child development—and the competence and quality of populations. Some of the findings from studies of ECD interventions in industrialized and developing countries are briefly summarized below. Key findings have come from:

- Lasting negative effects of institutional care
- Advantages of center- and home-based ECD programs, especially when combined
- Importance of integrating stimulation and nutrition programs
- The results from longitudinal, randomized controlled trials
- Influence of community and society in early child development.

Negative Effects of Institutional Care (Orphanages)

Children who are reared in institutions (i.e., orphanages) may suffer a lifetime of effects. Most orphanages cannot provide appropriate, loving care and nurturing, and most place young children at increased risk for infection, poor language development, and behavioral problems. Many children who are reared in orphanages become psychiatrically impaired and economically deprived adults.

Specific data show that infants and young children are vulnerable to the medical and psychosocial hazards and neglect associated with institutional care in most orphanages, and the negative effects are not reduced to a tolerable level later in adult life, even with massive expenditures.

In China, female infants and toddlers who are placed in orphanages because of the government's one-child policy and their parents' preference for males suffer great deprivation from passive neglect and lack of human contact.

Romania children who had been placed in orphanages and subsequently adopted into middle-class British, Canadian, and American homes had better cognitive development if they were adopted earlier, rather than later. Children who were adopted after spending 8 months or longer in orphanages had persistent, substantial deficits in development (Rutter and others 2004). Children who were adopted into middle-class Canadian homes after 8 months in a Romanian orphanage had lower school achievement, more attention-deficit disorders, and more behavioral problems, compared with those adopted earlier and Canadian children in middle-class families.

As countries strive to meet the needs of the ever-growing number of orphans resulting from the AIDS epidemic (e.g., in Sub-Saharan Africa), they have an opportunity to apply the new understanding gained about early child development to enhance the orphans' chances in life and their potential contribution to society.

These findings are all compatible with the data from the neurological and biological sciences that the quality of early child development in infancy has a major effect on subsequent development in relation to health, learning, and behavior.

Longitudinal Studies

The findings from longitudinal studies of birth cohorts have increasingly provided evidence about how the conditions of early life can affect health and development over the life course. A detailed study of the 1946 British birth cohort has provided evidence about how conditions in early life can set risks for both physical and mental health problems in adult life.

In studies of the 1958 British birth cohort, it was found that circumstances prevailing at each stage of child and adolescent development were relevant to the health differences among adults. In more recent work, further evidence was found that the manner in which brain and biological pathways develop in early life influences adult disease.

In a study of the 1970 New Zealand birth cohort, researchers came to the same conclusion that poor socioeconomic circumstances for early child development have long-lasting negative influences on adult health. They concluded that the socioeconomic gradient in health in adults emerges in childhood.

In studies of the relationship between birthweight, childhood socioeconomic environment, and cognitive development in the 1958 British birth cohort, it was found that the postnatal environment had an overwhelming influence on cognitive function. Birthweight had a weaker, but independent association. Low-birthweight children in the upper social class had better mathematics results than did low-birthweight children in the lower social classes at age 7 and 11 years. Furthermore, the school system did not change the performance for the low-birthweight children who were in the low social class.

Recent studies of the biological pathways and development in the 1958 British birth cohort at age 45 years have shown that the cortisol secretion patterns at age 45 is correlated with conditions influencing early child development. Cortisol secretion at age 45 is associated with the mathematical skills at ages 7–16 years reported in the earlier studies. This illustrates that

early brain development affects the stress (LHPA) pathways as well as the other pathways and that it is involved in learning and cognition (mathematics).

In the examination of the effect of child–parent centers in the Chicago Longitudinal Study, it was found that the child–parent centers located in or proximal to public elementary schools for children from ages 3 to 9 years enhanced child development when compared with children not in the program. A key finding was that there was significantly higher educational attainment and lower rates of juvenile arrest.

The results from this operational research project are compatible with the findings concerning experience-based brain development in the early years. Although this initiative enhanced early child development, the gains were probably less than what would have been achieved if the families with young children had been brought into center-based ECD programs involving parents at an earlier age.

The 1970 longitudinal British birth cohort studies clearly show that young children in center-based preschool programs do better in school than do children who are not in these programs. These studies show quite conclusively that preschool programs and parenting practices were important predictors of the mobility of children from all social classes in the school system. In further analysis of the 1970 British birth cohort, it was found that the development score at age 22 months predicted educational qualifications at age 26 years.

The overall conclusion from this study is that the majority of children who show low performance at the time of school entry are unlikely to have the process reversed within the present education programs when they are in the school system. These findings are all compatible with what we now know about experience-based brain development in the early years.

Home visiting is a widely used approach to help families with young children in industrialized and developing countries. This is an attractive strategy because it can bring support to socially or geographically isolated families, and the services can be tailored to meet the needs of individual families. Most of these programs not associated with center-based initiatives have produced modest benefits. This is perhaps not surprising since early child development is dependent upon the degree of the interaction of caregivers with infants and toddlers and the degree of social support. Center-based programs working with parents (including home visits) are better able to deliver an integrated “dose effect” for early child development.

The U.S. Infant Health and Development Program (IHDP) study of children from birth to age 3 years has examined cognitive and language development. The investigators found that the quality of the child’s program during this period has a significant effect on outcome by age 3.

Brooks-Gunn, Han, and Waldfogel (2002) have concluded that the provision of universal high-quality center-based childcare is beneficial to everyone, including children solely cared for by their mothers. They concluded that these positive benefits continued into the late elementary and high school years.

In studies of low birthweight, it was shown that center-based programs (for children ages 1–3 years) had a significant effect on WISC verbal scores at age 8 years. This good evidence is compatible with a dose effect in the 1–3 year age group on brain development in the early years of development for premature infants. Again, these findings are congruent with what we know about adequate and frequent stimuli influencing the biology of brain development in the very early years and that there is a dose effect in how neurons develop and form their synapses.

It is estimated that approximately 40 percent of children under age 5 years are stunted in developing countries. Grantham-McGregor and colleagues (1991) set out to examine the benefits for stunted children in Jamaica of nutrition and stimulation. They enrolled children ages 9–24 months whose height was two standard deviations less than the reference point for the age and sex of this age group.

The children were randomized to four groups: nutrition supplement; stimulation; stimulation plus nutrition supplement; and no intervention. The interventions were delivered in the homes through community health aides. The stunted children were compared with normal middle-class children of the same age. The children were followed for 24 months.

Both stimulation and nutrition improved development. Nutrition and stimulation together led to the stunted children matching the nonstunted groups' development after 24 months. The researchers concluded that stimulation and food supplementation had significant independent beneficial effects on the children's development. This shows that nutrition, by itself, does not produce the same effect as when it is accompanied by stimulation.

In this study, the researchers noted that the control group for the study came from a poor neighborhood and did not show the same development as a population of middle-class Jamaican children. At this age, the children who were stimulated showed a gain in intelligence quotient (IQ) and cognitive function, but this was less than the IQ and cognitive levels for nonstunted middle-class children. The children given only improved nutrition did not show a gain in cognition and IQ at ages 11–12 years.

There are a number of studies of ECD interventions in developing countries that show improved early child development (Young 1997, 2002).

Randomized Controlled Trials

The High/Scope Perry Preschool program in the United States found, in a randomized trial, that a center program during the school year for 3–4 year olds on weekday mornings along with a weekly 1.5 hour home visit to each mother and child on weekday afternoons during the school year had a significant effect on child development. Fifty-eight of these children were randomized to the preschool program, and 65 received no preschool program.

The children in the program significantly outperformed the no-program group. (Sixty-five percent in the program graduated from high school, in comparison with 45 percent of those not in the program.) A higher proportion of the children in the program went on to university. The children in the program performed much better on the literacy tests.

Another key finding from this Ypsilanti, Michigan, study was the substantial reduction in crime (reduced antisocial behavior) by the individuals in the intervention group. The reduction in antisocial behavior was substantial, leading to far fewer violent crimes, property crimes, or drug crimes.

The economic return to society of the program was \$258,888 per participant on an investment of \$15,166 per participant, or \$17.07 per dollar invested. Of that return, \$195,621 went to the general public (\$12.90 per dollar invested), and \$63,256 went to each participant (\$4.17 per dollar invested). Of the public return, 88 percent came from crime savings, 4 percent came from education savings, 7 percent came from increased taxes due to higher earnings, and 1 percent came from welfare savings (Schweinhart and others 2005).

Although this program had an initial effect on IQ, it was not sustained. This is perhaps not unexpected since the weight of the evidence today is that IQ is strongly influenced by the conditions during infancy. The Ypsilanti study is, by today's standards, a late intervention study.

It is better to start programs to enhance early child development when new mothers are pregnant and, certainly, when the child is born.

- See *“Outcomes of the High/Scope Perry Preschool Study and Michigan School Readiness Program,”* by Lawrence J. Schweinhart in this publication.

The Abecedarian project, a randomized trial in North Carolina provides important information about the value of early intervention with a high-quality ECD program on cognitive development over more than 20 years. In this program, a group of African American children whose mothers had IQs ranging from 74 to 124 (average, 85) were randomized initially into two groups: a control group, and a group exposed to a preschool center-based program starting at age 4 months.

At the time of school entry, the intervention group was randomized into two groups, one of which was put into a special school program for the first 3 years and the other of which went into the normal school program. The control group was also randomized into a group given the special 3-year education program in the school, and the others were given the standard educational program.

The control group randomized at the time of school entry showed, for the group given the special 3-year program, better performance in reading skills than the control group that was not randomized to the school program. The children in the original preschool intervention group randomized to the 3-year school program showed substantially improved skills in reading and mathematics throughout the period in the school system. The children in the preschool program not placed in the special 3-year school program lost a significant portion of their gain by age 21 years, in contrast with the group from the preschool program that also had the special 3-year program in the first 3 years of school. The findings for mathematics showed a benefit of the preschool program.

This study showed that integration of the preschool and school program produced the greatest gains in reading.

This evidence is compatible with there being brain-sensitive periods in the early years for language and literacy development, which influence later periods of development in the school system. The preschool program clearly enhanced performance in the school program.

The evidence is compatible with the conclusions from the neurosciences and biological sciences that, to improve literacy, the investment in the preschool period is important.

The effects of the preschool program, with meaningful effect sizes on reading and mathematics skills, have persisted into adult life. The 3-year program in the school maintained the preschool benefits for reading. The 3-year school program for children not in the preschool program had an effect, but it was weaker than the effect for children who had the preschool-plus-school program.

- See “*The Abecedarian Experience*,” by Joseph Sparling, Craig T. Ramey, and Sharon L. Ramey in this publication.

Summary

The results from these and other studies are compatible with the evidence from the neurosciences and biological sciences that the critical and sensitive periods for brain and biological development are significantly influenced by experience in the early years beginning with pregnancy. Later interventions have a limited effect.

A substantial investment in early child development will be necessary if we are to improve the competence, health, and well-being of populations throughout the world.

Ingredients of Success

The best ECD interventions are comprehensive, integrated programs involving parents that combine nurturing and care, nutrition, and stimulation. They focus on the whole child and involve families and communities. Most importantly, they begin early, preferably when a mother is pregnant or soon after she gives birth.

The essential ingredients for successful, effective ECD programs are outlined in *The Early Years Study: Reversing the Real Brain Drain* (McCain and Mustard 1999), a report to the Government of Ontario, Canada. The ingredients outlined in this report include:

Support for Caregivers. Early child development is profoundly affected by the quality of caregiving children receive and the degree of support provided to parents and caregivers. ECD initiatives should include both prenatal and postnatal support.

Involvement of Parents and Institutional Support. Initiatives to ensure high-quality early child development must involve parents and have appropriate institutional support. They should arrange for nonparental care (i.e., day care), effective interaction of children with caregivers and other children, and participation of nonworking mothers.

Optimized Development. Programs should optimize development of sensory pathways during all periods of early child development (infancy, toddlerhood, and young children). Environments should be healthy and have adequate resources for reading and “play-based learning.” If properly designed, play-based learning is actually problem-based learning—one of the best strategies for brain development and for learning.

An Integrated Approach. Home visiting is useful for augmenting center-based ECD initiatives. Integration of ECD programs with primary schools is important and, logically, kindergartens should become part of ECD centers.

The three important principles for improving early child development as set out by Ludwig and Sawhill (2006) are:

- Intervene early.
- Intervene often.
- Intervene effectively.

These three principles are in accordance with *all* of the evidence on early child development—from neuroscience, biology, population health, and behavioral and social science. The data and findings from the many and various ECD interventions worldwide convey the same message.

Investing in Early Child Development: The Rationale and the Returns

Investing in early child development *must* be a major objective in all regions of the world, to:

- Reduce the proportion of populations living in poverty
- Improve equity in literacy, health, and income
- Reduce violence
- Enhance social stability
- Improve the quality of human capital
- Embrace the opportunities in modern, knowledge-based economies
- Be successful in the continuing experiments in civilization
- Sustain the biosphere for future populations.

Assuring universal access to high-quality ECD programs is a basic step toward reducing poverty, promoting equity, and building human capital—determinants of economic growth and civic societies. The importance of society’s human capital has long been recognized by Nobel laureates in economics (Tinbergen, Schultz, Fogel, Sen).

More recently, the specific value of investing in early child development has been noted by leading economists. Van der Gaag (2002) brings together all the points about human development to conclude that early child development affects education, health, social capital, and equity and fosters a “level playing field” among all individuals—a key aspect of stable societies and economic growth.

During our time in human history, the exponential growth in knowledge and advanced technologies cannot be sustained unless societies build competent, equitable, high-quality populations and stable, prosperous communities. Failing to make the necessary investments to ensure the quality, competence, and equity of future populations could lead to chaos and grim prospects for the continuing experiments in civilization.

Fortunately, the return on investing in early child development is high. Heckman (2000), another Nobel laureate in economics, has recently concluded:

The return for every dollar invested in preschool is much greater for the individual and society than is an investment in school-based programs. The return on investments in ECD programs is at least 8:1, compared with the return on investment in education in general, at 3:1. [This calculation does not include the effects of ECD programs on physical and mental health in adult life.]

Heckman (2000) goes on to say—

We cannot afford to postpone investing in children until they become adults nor can we wait until they reach school—a time when it may be too late to intervene.

Achieving improvements in early child development will be particularly challenging in developing countries. In Africa alone, for example—

- More than 20 percent of 140 million children are at very high risk for poor development.
- More than 95 percent of these young children do not have access to ECD programs that provide healthy environments, good nutrition, and stimulation.
- The children who do not attend school constitute nearly 50 percent of all of the world's children who do not attend school.
- Orphans will comprise 20 percent of all children under age 15 years—in 12 countries devastated by AIDS, war, and civil strife.

International agencies, including the World Bank, United Nations, and other organizations, must increase their support and leadership to assist these countries in closing the gap between *what we know* and *what we do* about early child development.

With 50 percent of the populations in Canada and the United States showing poor literacy, industrialized countries also must expand their investments and efforts in early child development to improve the competence and quality of their populations—and to help demonstrate how best to apply the knowledge being gained to ECD programs throughout the world.

All countries must work together to close the gap in early child development and to improve the health, well-being, and competence of the world's populations. This is very important for our continuing experiments in civilization.

Web Resources [as of November 2006]

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References

- Acheson, D. 1998. *Independent Inquiry into Inequalities in Health: Report*. London: The Stationery Office.
- Biederman, J., and S. V. Faraone. 2005. Attention-Deficit Hyperactivity Disorder. *The Lancet* 366:237–48.

- Brooks-Gunn, J., W.-J. Han, and J. Waldfogel. 2002. Maternal Employment and Child Cognitive Outcomes in the First Three Years of Life: The NICHD Study of Early Child Care. *Child Development* 73(4):1052–72.
- Casassus, J. 1998. *First International Comparative Study of Language, Mathematics, and Associated Factors in Third and Fourth Grade*. Santiago, Chile: UNESCO (United Nations Educational, Scientific, and Cultural Organization).
- Drukker, J. W., and V. Tassenaar. 1997. Paradoxes of Modernization and Material Well-Being in the Netherlands during the Nineteenth Century. In R. H. Steckel and R. Floud, eds., *Health and Welfare during Industrialization*. Chicago: University of Chicago Press.
- Fogel, R. W. 1994. *Economic Growth, Population Theory, and Physiology: The Bearing of Long-term Processes on the Making of Economic Policy*. National Bureau of Economic Research Working Paper No. 4638. Cambridge, Mass.: NBER.
- Fogel, R. W. 2000. *The Fourth Great Awakening and the Future of Egalitarianism*. Chicago: University of Chicago Press.
- Fukuda-Parr, S., 2004. *Human Development Report 2004: Cultural Liberty in Today's Diverse World*. New York: United Nations Development Programme.
- Grantham-McGregor, S. M., C. A. Powell, S. P. Walker, and J. H. Himes. 1991. Nutritional Supplementation, Psychosocial Stimulation, and Mental Development of Stunted Children: the Jamaican Study. *The Lancet* 338(8758):1–5.
- Hebb, D. O. 1949. *The Organization of Behavior*. New York: Wiley.
- Heckman, J. J. 2000. *Policies to Foster Human Capital*. Joint Center for Poverty Research Working Papers 154. Chicago: Northwestern University/University of Chicago.
- Hubel, D. H., and T. N. Wiesel. 1965. Binocular Interaction in Striate Cortex of Kittens Reared with Artificial Squint. *Journal of Neurophysiology* 28:1041–59.
- Kandel, E. R. 2001. The Molecular Biology of Memory Storage: A Dialogue between Genes and Synapses. *Science* 294:1030–38.
- Keating, D. P., and C. Hertzman. eds. 1999. *Developmental Health and the Wealth of Nations: Social, Biological, and Educational Dynamics*. New York: The Guilford Press.
- Lewis, M. H., J. P. Gluck, J. M. Petitto, L. L. Hensley, and H. Ozer. 2000. Early Social Deprivation in Nonhuman Primates: Long-term Effects on Survival and Cell-mediated Immunity. *Biological Psychiatry* 47:119–126.
- Ludwig, J., and I. Sawhill. 2006. *Success by Ten: Intervening Early, Often, and Effectively in the Education of Young Children*. Washington, D.C.: The Brookings Institution.
- Marmot, M., 1994. Social Differentials in Health. *Daedalus* (fall).
- McCain, M. N., and Mustard, J. F. 1999. *Early Years Study: Reversing the Real Brain Drain*. Toronto: Publications Ontario.
- McEwen, B. 2002. *The End of Stress as We Know It*. Washington, D.C.: Joseph Henry Press.
- McKeown, T. 1976. *The Modern Rise of Population*. New York: Academic Press.
- Meaney, M. J., and M. Szyf. 2005. Maternal Care as a Model for Experience-dependent Chromatin Plasticity? *Trends in Neurosciences* 28(9):456–63.
- OECD (Organization for Economic Cooperation and Development). 2005. *Learning a Living: First Results of the Adult Literacy and Life Skills Survey*. Paris: OECD.
- OECD and Statistics Canada. 2000. *Literacy in the Information Age: Final Report of the International Adult Literacy Survey*. Paris: OECD.

- Rutter, M., T. G. O'Connor, and the English and Romanian Adoptees (ERA) Study Team. 2004. Are There Biological Programming Effects for Psychological Development? Findings from a Study of Romanian Adoptees. *Developmental Psychology* 40(1):81–94.
- Schweinhart, L. J., J. Montie, Z. Xiang, W. S. Barnett, C. R. Belfield, and M. Nores. 2005. *Lifetime Effects: The High/Scope Perry Preschool Study through Age 40*. Ypsilanti, Mich.: High/Scope Press.
- Sternberg, E. M. 2000. *The Balance Within: The Science Connecting Health and Emotions*. New York: W. H. Freeman and Company.
- U.S. Department of Education. 2002. *Adult Literacy in America: A First Look at the Findings of the National Adult Literacy Survey*. Washington, D.C.
- Van der Gaag, J. 2002. From Child Development to Human Development. In M. E. Young, ed., *From Early Child Development to Human Development*. Washington, D.C.: World Bank.
- Willms, J. D. 2002. Standards of Care: Investments to Improve Children's Educational Outcomes in Latin America. In M. E. Young, ed., *From Early Child Development to Human Development*. Washington, D.C.: World Bank.
- Young, M. E., ed. 1997. *Early Child Development: Investing in our Children's Future*. Amsterdam: Elsevier.
- Young, M. E., ed. 2002. *From Early Child Development to Human Development*. Washington, D.C.: World Bank.