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Early Childhood Neglect, Toxic Stress, and Neurodevelopment

Primera infancia, estrés tóxico y neurodesarrollo

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Abstract

Several and recent neuroscientific studies have accumulated empirical evidence about the maturation and neurodevelopmental processes that occur in the human brain during the first months and years of life. This immaturity gives the human brain under construction greater plasticity and learning capacity, but also leads to greater vulnerability to harmful and toxic agents from the environment. Therefore, it is considered that the care quality received in early childhood and child abuse in the form of emotional neglect, directly influence the architecture and functionality of the developing brain, both of which would elicit physiological responses of chronic and sustained (toxic) stress, being a key risk factor for the development of both physical and mental illness (anxiety and depression) in adolescence and adulthood. In this sense, a prevention model is proposed in which the first caregivers (family and school) act appropriately contributing to improve school success.

Keywords: neurodevelopment, early childhood, parenting, neglect, toxic stress

Resumen

Varios y recientes estudios neurocientíficos han acumulado evidencia empírica sobre la maduración y los procesos del neurodesarrollo que ocurren en el cerebro humano durante los primeros meses y años de vida. Esta inmadurez le da al cerebro bajo construcción gran plasticidad y capacidad de aprendizaje, pero a la vez lo deja con mayor vulnerabilidad a los agentes tóxicos y dañinos del medio ambiente. De esta manera, se considera que la calidad del cuidado recibido en la niñez temprana y el abuso en forma de negligencia emocional influyen directamente sobre la arquitectura y la funcionalidad del cerebro en desarrollo. Ambos producen una respuesta psicológica de estrés (tóxico) crónico y sostenido, lo cual es un factor de riesgo para el desarrollo tanto de enfermedades físicas como mentales (ansiedad y depresión) en la adolescencia y la adultez. En este sentido, se propone un modelo de prevención en el cual los primeros cuidadores (familia y colegio) actúan apropiadamente contribuyendo para mejorar el éxito escolar.

Palabras clave: neurodesarrollo, primera infancia, paternidad, negligencia, estrés

Recent neuroscientific studies confirm that the first years of a child's life, when the maturational processes of the central nervous system (CNS) entail the most dramatic neurological changes and are accompanied by greater cerebral plasticity, are key to its optimal neurodevelopment (Pujol et al. 2006). In these first years of life, the human brain is going to change dramatically. First of all, an overproduction of neural connections (synaptogenesis) and the greatest dendritic growth will take place (Hair et al., 2015), and secondly, different periods of programmed neural pruning and myelination will be shaping and organizing the neural architecture necessary for subsequent cognitive and behavioral functioning (Durston & Casey, 2006; Giedd & Rapoport, 2010).

In this sense, the neuroscientific advances point out that caregivers must attend this early brain growth correctly, because it will not be repeated at this same pace later, and it can have a powerful impact on their cognitive, emotional and social development; and on their physical and mental health, both in childhood and in adulthood (Fields, 2008; Hüppi, 2008).

Ensuring the physical and mental well-being of a child means taking into account the cognitive and socio-emotional capacities of their development. In fact, affection is a source of cognitive and physical development and mental health (Brazelton, 2005). Just as care quality received, the attachment quality (Bowlby, 1951; Ainsworth et al., 1978) provide the child with the necessary security to develop in a healthy way, and are the base of the personality construction and sociability.

On the other hand, if the care received by the child and the environmental conditions where he develops are unfavorable during these early years, the subsequent toxic stress (chronic and sustained) that the kid will suffer could affect the child's neurodevelopment and lead to long-term disruptive effects that would affect both the learning processes, as well as the behavior and the physical and mental wellbeing of the child over the years (Center on the Developing Child at Harvard University, 2014).

The challenges of inclusive, equitable and quality education demanded by this 21st century, according with the proposals of the 2030 Agenda for Sustainable Development (United Nations), point the way: to ensure that all children have access to early childhood care and development services and quality education.

In this way, equality of opportunity, educational equity, school success and the generation of human capital must be guaranteed in order to get out of poverty, and this is what several researchers point out, it will be necessary to invest in the first years of a child's life (Heckman, 2011) improving the environments quality such as families, nursery schools and neighborhood, and the ability to detect, as soon as possible, the negative environments that can generate not only school failure and dropout but also deficits in health and labor, social, family and even criminal instability (Heckman, et al., 2010).

The importance of the first years

From an interdisciplinary theoretical perspective, that begins with the systemic concept of health, the following question arises: to what extent do the early experiences, the social and family environment that a boy or a girl live in during the first months and years of his or her life, leave a lasting mark in the genetic predispositions that affect the kid's emerging brain architecture and long-term health?

A few decades ago it was believed that the genetic inheritance determined an important percentage of the child's life, but nowadays it is known that both parts, heritage and environment, interact and influence each other, nature versus nurture (Sameroff, 2010; Morena & Olmos, 2015). In this sense, the ecology of the child affects his biology and this impacts (in a positive or a negative way) development and health throughout life. This influence is especially relevant in the first months and years of life, since this is when the brain is more immature and, therefore, is more plastic, easily influenced and moldable by the environment and in turn, more vulnerable to possible negative environmental agents, especially the effects of chronic and toxic stress (Britto et al, 2017).

The human species is the animal species that is born more immature, some authors even defend that newborns are still fetuses for a few months after birth, they defend that we are clearly born prematurely due to our phylogenetic development: as the hominids became bipedal, the cranial volume increased while the female pelvis became narrower to be able to walk long distances and we began to born sooner. (Rosenberg & Trevathan, 2002).

This immature birth translates into a very prolonged childhood, so that human offspring depend on adults of their species for many years to survive. This evolutionary design, which could easily seem a great inconvenience for the survival of the species, is in fact a great evolutionary advantage. This immaturity gives the human brain a greater degree of plasticity and a learning capacity that is not comparable to other animal species (Gould, 2010).

During the first months of pregnancy, almost all the neurons that we will have throughout our lives are created (more than 100 million neurons) but at the moment of birth they are immature. These neurons are not functional, they need to branch out and connect with other neurons to myelinate for optimal performance. Already during this period, the development of the brain is exposed to the influence of the environment through symbiosis with the mother. So that food, stress or any toxic agent to which the pregnant mother is exposed will directly influence in the neurodevelopment of the fetus (Ackerman, 1992).

The neuronal maturation includes the growth of neuronal, axonal and dendritic prolongations, and this growth implies the establishment of synaptic contacts (synaptogenesis) that will allow the transmission of nerve signals and the neural communication that sustains the development of the children´s capacities. In the first months and years of life, synaptogenesis is spectacular: it is said that the brain sprouts, and many neuronal connections are created, up to 10,000 synapses per neuron, more than our mature brain will be able to sustain and will end up needing.

That is why after a few years, and at different rates in different brain regions, a process of selection of synapses begins and the brain loses all those connections that have not been stimulated by the environment because they are not useful for adaptation to the environment. In this sense, all those connections that have been enhanced and stimulated by the environment will last, and those that will not, will be lost with the aim of making the brain more efficient and adapted to its environment. This process is known as synaptic pruning or neural pruning (Figure 1) and, although it may seem like a loss to our brain, it is absolutely necessary that it takes place so that the brain can specialize and be more efficient in those skills that are necessary for it.

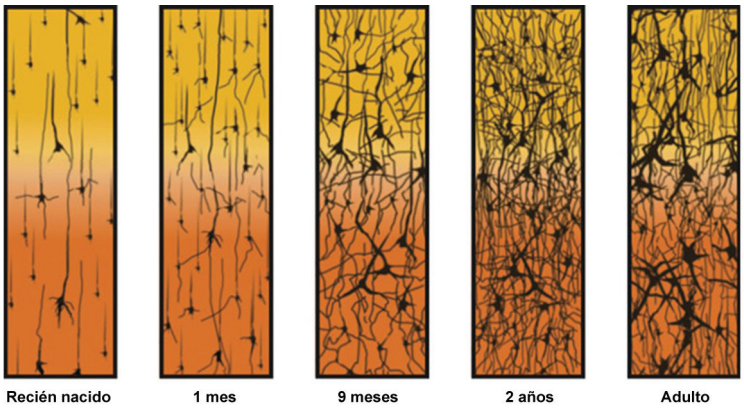

Figure 1: Synaptic density throughout neurodevelopment (Source: Corel, 1975)

The last step in neuronal maturation is the myelination or maturation index of the white matter of the brain. Myelination is a process in which the glial cells cover neurons axons with myelin, a lipoprotein that acts as an insulator and accelerates nerve transmission, which facilitates a faster and more efficient processing of neuronal information. Myelination begins at three months of gestation and lasts long after birth, up until almost thirty years of life (Sowell et al., 2003).

In this sense, the development of the CNS follows a temporal pattern of increasing complexity, although at birth only the most primitive and instinctive structures, phylogenetically speaking, would be myelinated in order to guarantee the survival of the newborn outside. The rest of the brain, and especially the cortex, follows a pattern of myelination parallel to the complexity of the functions they control. First, the primary sensory and motor areas are myelinated and finally the association cortices, such as the parietotemporoccipital cortex and, above all, the prefrontal cortex, the most modern phylogenetically and responsible for the highest-level cognitive functions (Sowell et al., 2003).

The maturation and development of the brain is a long and progressive process that takes place in parallel with the cognitive development of the child. The complexity of the cerebral cortex and myelination correlate with the development of, progressively more elaborate, behaviors. Since the deve-

lopment of any capacity, whether motor or cognitive, will always depend on the maturation of the brain structures that sustain it.

These stages of brain development or maturation suggest the existence of what have been called critical or sensitive periods of development. These periods are considered temporary windows in which the brain is more receptive or is more prepared to receive a certain type of stimulation, which would allow the development of certain specific capacities before the pruning process occurs in that region.

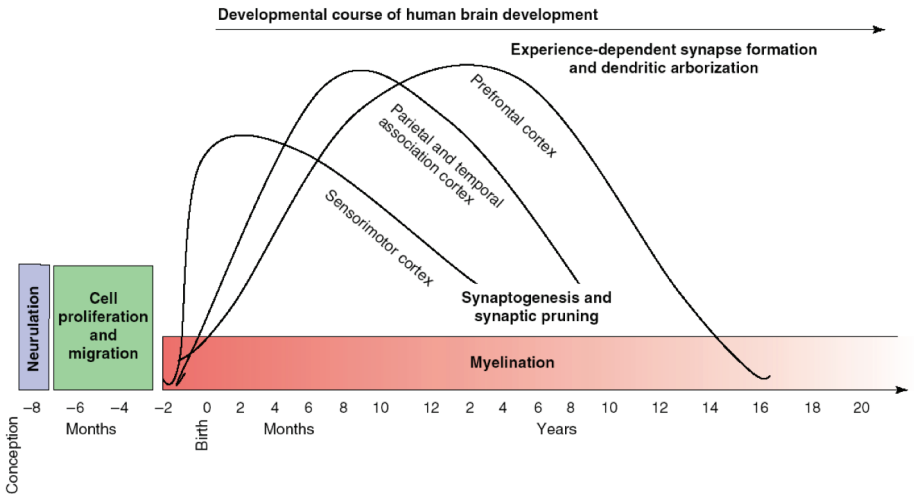

Figure 2: Periods of synaptogenesis and neural pruning along neurodevelopment (Source: Thompson & Nelson, 2001)

Both periods can be considered as of opportunity and vulnerability, since the stimulation in these periods is fundamental for the correct acquisition of skills, both cognitive and behavioral, and if this stimulation was not to be given or was not the desired one, its acquisition could result altered or diminished favoring the presence of psychopathologies, endocrine alterations and maturational delays that could extend into adolescence and adulthood (Beckett et al., 2006; Carlson & Earls, 1997; O'Connor et al., 2000).

Parenting and parenting styles

Although the maturation and growth of the CNS is genetically programmed (Stiles & Jernigan, 2010), the influence of the environment plays a decisive role in neurodevelopment starting with the pregnancy and all the way throughout childhood and adolescence. Thus, the family environment, the parents, the parenting style, the care received, the neighborhood or the nursery school that this child attends are important factors to take into account (Brofenbrenner, 2005).

There are two almost opposite types of parenthood and in the middle, there is a broad spectrum. The first would be desirable for the good development of the child: sensitive, responsive, affective and consistent. The second, however, would be insensitive to the needs of the child, inconsistent and negligent, and may not cover some physical needs and especially many of the child's emotional needs (Landry et al., 2006).

When paternity is so negative that it involves some sort of risk and lack of protection of the child, it starts being child abuse (Hibbard et al., 2012; Arruabarrena, 2011) specifically the type known as emotional neglect. There is no violence, neither physical nor sexual, therefore there are no obvious physical signs, but there is an emotional and affective abandonment accompanied by elements of psychological aggression. The figure of attachment (that should provide the emotional security necessary for the development of the child) becomes a source of insecurity and sustained stress (Arruabarrena, 2011; Arruabarrena, and De Paul, 1996; De Paul and San Juan, 1992).

Emotional neglect is, often, an almost invisible abuse. It goes unnoticed and it is very harmful, given that with it begins a negative process in the development and health of the child, linked to chronic and toxic stress responses that generate harmful effects throughout life. Invisible for negligent parents who are far more aware of their needs than those of their children, and invisible to a nursery school in which often these cases go unnoticed given the high student-teacher ratio, but very visible for neuroscience thanks to the latest neuroimaging and psychophysiological studies.

Physiological stress response

Several studies have observed the physiological responses to stress that a child can suffer in the first years of life (Gunnar, 1998, Gunnar & Quevedo, 2007, McEwen, 2007). The most studied response is the one that involves the activation of the hypothalamic-pituitary-adrenal axis (HHA axis) and the sympathetic-adrenomedular system whose activation generates the increase on the levels of stress hormones and the increase in the proinflammatory cytokines.

Stress is a physiological response of our body to a threatening stimulus that prepare us to flee or fight (raises the heart rate, dilates the bronchi, increases blood pressure, decreases digestion, ...) and thus seek for our survival. In the face of a stressful or threatening stimulus, the limbic system (specially the amygdala) gets activated and activates, in turn, the HHA axis. Through the paraventricular nucleus of the hypothalamus, vasopressin and corticotropin-releasing hormone (CRH) are synthesized and secreted, which send signals to the pituitary gland (or hypophysis) to secrete the adrenocorticotropic hormone (ACTH), which in turn, and released into the bloodstream, sends signals to the adrenal glands (located above the kidneys) to produce glucocorticoid hormones, mainly cortisol, considered the stress hormone, as well as adrenaline and noradrenaline. These glucocorticoids in the blood, in parallel, will act on the hypothalamus and the pituitary gland through the receptors located on the hippocampus to inhibit the production of CRH and ACTH, and thus reducing the activity of the HHA axis and the stress response, in a cycle of negative feedback.

The temporary increases of these stress hormones have a protective and even fundamental function in survival: in fact, the psychophysiological mechanisms of the stress response play a fundamental role in the process of adaptation and survival and this is within the normality of an organism that responds to environmental threats. However, when the level of these hormones is excessive or there is a prolonged exposure to them, this circumstance can end up being very harmful or truly toxic (McEwen, 2005). In such a way that this deregulation starts a chronic effect of deterioration on several apparatus and systems such as the CNS, the immune system, the endocrine system and the cardiovascular system (McEwen, 2003).

However, not every stress response is bad. If the evolution of our brain has conserved it, it is because it has an evolutionary meaning for our survival. The Harvard Child Development Center (2012) has proposed a classification in which there are three types of stress responses present in the youngest children considered: positive, tolerable and toxic stress.

Positive stress response is a normal and essential part of a healthy development, characterized by brief increases in heart rate and mild elevations in hormone levels. Some situations that might trigger a positive stress response are the first day with a new caregiver or receiving an injected immunization.

Tolerable stress response activates the body's alert systems to a greater degree as a result of more severe, longer-lasting difficulties, such as the loss of a loved one, a natural disaster, or a frightening injury. If the activation is temporary and buffered by relationships with adults who help the child adapt, the brain and other organs recover from what might otherwise be damaging effects.

Toxic stress response can occur when a child experiences strong, frequent, and/or prolonged adversity—such as physical or emotional abuse, chronic neglect, caregiver substance abuse or mental illness, exposure to violence, and/or the accumulated burdens of family economic difficulties—without adequate adult support. This kind of prolonged activation of the stress response systems can disrupt the development of the brain architecture and other systems, and increase the risk for stress-related disease and cognitive impairment, even well into the adult years.

As this classification shows, one of the key factors for protection in the face of sustained stress response is social support and, above all, a receptively sensitive paternity that will lead to a secure attachment with the parents or caregivers. The attachment is the emotional bond that is established between the child and their caregiver, or main caregivers, which provides the necessary security for healthy development and is the basis of their emotional life on which they will build their future personality. The establishment and quality of this link will depend, mainly, on the sensitive receptivity of parents or caregivers who know how to interpret the needs

of the child and adapt their behavior to these needs to cover them effectively (Raikes, & Thompson, 2008; Prior & Glaser, 2006; Bornstein, 2002).

In this sense, early quality care, affectionate and responsive to the real needs of the child as a support to face and overcome the stressors and negative situations that life may present, helps the construction of a more resilient and assertive personality. The attention given becomes then a protective factor for the development of both physical and mental illnesses.

Toxic stress in early childhood and neurodevelopment

In addition to the short-term changes in observable behavior, toxic stress also has non-visible but acute and permanent consequences on the structure and function of the brain (McEwen, 2006; 2007).

Given the high plasticity of the brain in these early stages, even in the fetal period, when this immature organ suffers high levels of stress hormones in a chronic and sustained manner, its structure and architecture can be disorganized, at different levels and aspects (McEwen, 2008; Teicher et al., 2016).

More specifically, chronic stress is associated with hyperactivity in the amygdala (Roozendaal et al., 2009) that will make this brain more vulnerable and respond more easily to stress, starting a vicious cycle of: more stress, greater response to stress. On the other hand, chronic stress can lead to the loss of neurons and neuronal connections in the hippocampus (De Quervain et al., 2009), a structure especially related to learning and memory processes, and in the prefrontal cortex (PFC). (Arnsten, 2009), neurological headquarters of the main executive functions (working memory, planning, inhibitory control, flexibility, ...) (Diamond, 2013).

The functional consequences of these structural changes (Figure 3) suppose more anxiety related to both the hyperactivation of the amygdala and less control as a result of atrophy of the PFC. All this supposes a deterioration of the memory and the control of the state of mind as a result of the reduction of the Hippocampus (McEwen & Gianaros, 2011)

so that the development of the cerebral architecture can be affected with important consequences throughout the life.

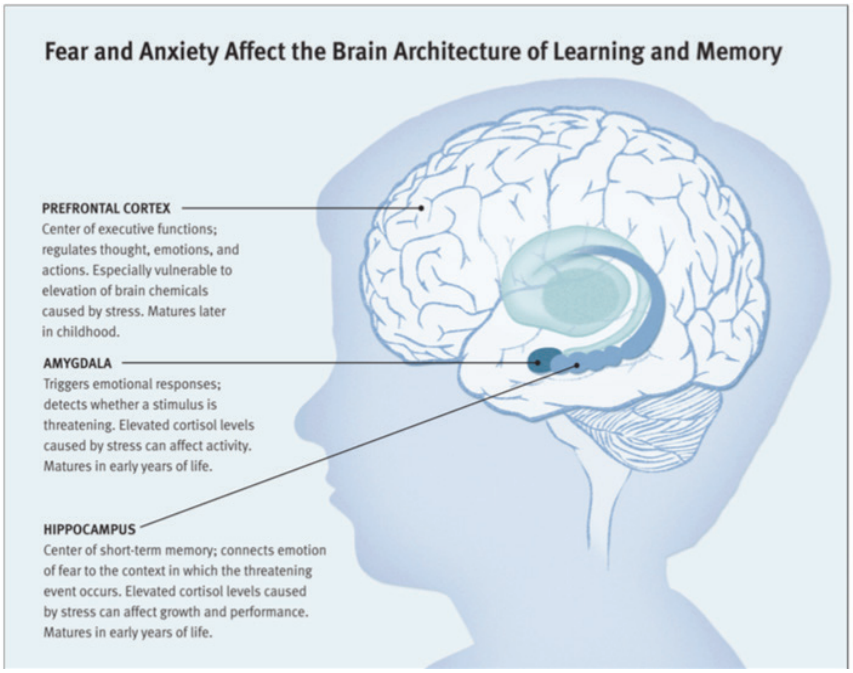

Figure 3: Effects of chronic and toxic stress on the developing Central Nervous System (Source: National Scientific Council on the Developing Child, 2010)

On the other hand, chronic stress attenuates the negative feedback that glucocorticoids in the blood and in the stress response must perform on the hypothalamus and pituitary gland to reduce the release of CRH and ACTH and inhibit the HHA axis. Meaning that a sustained stress response reduces the ability of the organism itself to inhibit this, thus generating greater chronic stress (Mizoguchi et al., 2003).

These changes can extend throughout development. Several studies with animals show that these stressful life experiences during childhood have persistent effects on hormonal regulation and stress responses in adulthood (Kloet, et al., 1996; Sebaai, et al., 2002; Workel, et al., 2001) making subjects more vulnerable and reactive to stress.

Similar results have been obtained in studies with humans. It has been observed that 3-month-old babies who have received responsive care from their parents produce less cortisol at baseline, and that 18-month-old boys and girls with insecure attachment produce more cortisol than those who have a secure attachment (Nachmias et al., 1996), proving that an insecure attachment is a key factor for behavioral and physiological stress responses, as well as for the possible development of depressive psychopathology both in childhood and in adulthood (Beatson & Taryan, 2003; Gunnar et al., 1996; Luby et al., 2003; Spangler & Grossmann, 1993).

In addition, several studies have linked a chronic stress response with an alteration in the oxytocin system, a hormone, also secreted by the pituitary gland, which has been involved in the recognition and establishment of social relationships, trust and generosity between people (Zak et al., 2007), and who normally performs a modulating role on stress by inhibiting its response (Windle et al., 2004). This means that the alteration in this system due to early experiences of toxic and chronic stress such as mistreatment or parental separation, may contribute to a greater vulnerability to the pathogenic effects of stress (Heim et al., 2009; Meinlshmidt & Heim, 2007).

The relationship between Adverse Childhood Experiences (ACE) and unhealthy lifestyles has been well documented (Shonkoff et al., 2012). ACEs suffered in childhood have been related to risky behaviors such as smoking, obesity, promiscuous behavior, gambling, learning problems and school failure (Wickrama et al., 2008).

On the other hand, toxic stress in childhood can generate alterations in the immune system in adulthood, high levels of markers of inflammation, autoimmune diseases (Dube et al., 2009), cardiovascular diseases and diabetes associated with personality types. A (Luecken, 1998), asthma, and depression among some others as indicated by the pediatricians around the world. (Shonkoff et al., 2012).

Finally, recent studies have observed that this toxic and sustained stress can produce changes at the epigenetic level (affecting the expression of genes), changes that can even be transmitted to the offspring so that

parents suffering from toxic stress can have children and daughters more sensitive to stress (Shonkoff, et al., 2012).

Discussion-conclusion: care in early childhood

The pediatric community of the United States of America has insisted for some years that we must approach the origin of diseases, disorders and impediments that will result in poor health during adult life. It is a new preventive approach that focuses in the first months and years of life and calls for change in the care model; from a sick-care health model to a well-care model (Schor et al., 2007), since the sick-care model is economically unsustainable because of its costs—for the welfare state—and because of the increases in population and life expectancy.

For this model to become functional, it is necessary to involve various groups of professionals, such as educators, sociologists or pedagogues, who can really detect the problems of neglecting children and mitigate them before the damage is irreversible. The risk factors that derive from the complex social, economic, cultural, and environmental framework that lead to health inequalities in different types of population end up being unsustainable from the point of view of health expenses (Shonkoff et al., 2009; Bronfenbrenner, 2005).

Socio-educationally, it is sought to measure the conditions of possibility of a parenting, a nursery school and a pediatric care that, among other things, are aware, in their areas of specialization, of how to undertake psychological abuse. Subtle mistreatment is the most widespread among children, which can be the basis of many problems of development and health throughout life. Noticeable prevalence of psychological abuse in children (Glaser, 2002), which includes emotional abuse and neglect, is 71% in England (Figure 5).

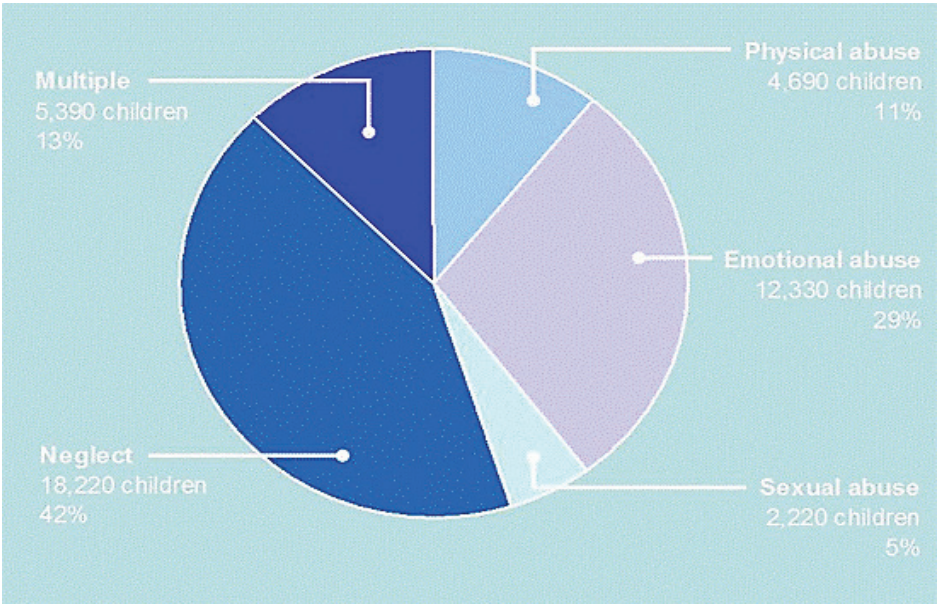

Figure 4: Prevalence of the different types of abuse in the English child population (Source: Department for Education, 2012)

Numerous adult diseases must be understood, studied and confronted as developmental disorders that begin very early in life: in upbringing and a concrete sociocultural and urban framework. And here inequality begins. Here the social elevator begins to break, the disadvantaged classes are multiplied and the cycle of poverty is perpetuated (Braveman & Barclay, 2009).

Public policies and private initiatives that want to help the improvement of early childhood should make the range of their analysis bigger. It is no longer just a matter of departments: psychological, biological, sociological, pediatric or neuroscientific. It is an issue where different disciplines converge. From this perspective, educators must situate themselves in a specific point, in a stage of this circular model, to make observation, detection and referral whenever necessary. Also to direct the interventions that train children and parents in family stability, in parenting linked to development.

In this sense we can point out, according to the work of Knudsen and colleagues (2006) that there is not enough investment in educational

objectives in early childhood, but that we must reduce, in parallel, family adversity to strengthen the foundations of a development and a satisfactory physical and mental health. It is starting to exist a solid research base that points out that dealing with health, learning and behavior in early childhood means investing in the future of citizenship.

When it comes to improve learning and performance of future citizens, some economists also argue, as Heckman (2006), in favor of investments in early childhood, such as the quality of the nursery school. These actions must be regular and sustained and must focus on the care and education of the youngest children through proven, recognized programs, particularly for children from families with economic difficulties and low incomes.

This way, it has been observed that investment in education of families and teachers of infant schools affects the cognitive and non-cognitive progress of the children and students and offers a return -measured in terms of cost- benefit- in a ratio of 1 to 9 per dollar invested (Heckman, 2001). The key, then, is the quality of early childhood development, in family and care environments, as a predictor of the future human capital and national productivity of any state (Pérez-Escamilla and Moran, 2017).

With programs tested we refer to works that have received a longitudinal follow-up and have shown that, in rigorous cost-benefit tests, the return generated by these investments becomes an obvious saving for the health and safety budgets of the State and also in the form of human capital growth (Heckman et al., 2006) (Figure 5).

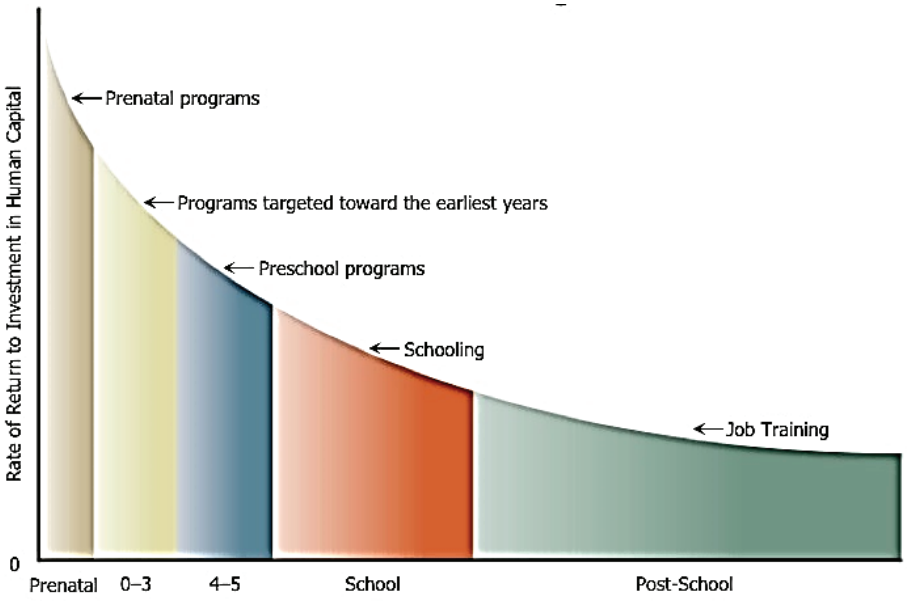

Figure 5: Investments in early childhood become investments in human capital (Source: Heckman, 2012)

These models talk about potential savings in health care costs and also small marginal reductions in the prevalence of cardiovascular diseases, hypertension, diabetes, depression. Economic productivity depends on these aspects, less disease, more well-being and greater productivity.

There are, therefore, programs applied to early childhood (Perry Program, Nurse Family, Abedecedarian Project) that have been studied in their longitudinal results and the returns per invested dollar have moved in a range between $ 3 and $ 9. Effective interventions in early childhood have documented these benefits (Karoly & Bigelow, 2005; Heckman et al., 2010).

Prospective

As noted above, toxic and chronic stress in early childhood is not only a risk factor for the subsequent physical and mental health of people but also becomes a true biological injury that will manifest itself in one way or another after some time. In these cases, the toxic stress generates a biological memory

that supposes a risk for a lifetime and to ignore this reality makes well-being very expensive for the state, and not only because of the health cost, but also by the consequences in life quality of certain communities, and even in the labor force efficiency and productivity, human capital quality of a society that has to prosper in a demanding and competitive globalized world from an economic point of view.

In this sense, it is necessary and interesting to put in the political, social and educational agenda of our country the following considerations. This require an interdisciplinary collaboration from different professional fields to improve school success, human and social capital of our country: (1) the implementation of training in responsive parenting for parents of boys and girls in early childhood, and subsequently, (2) a political and legislative project that manages to increase the quality standards of the children's educational stage (Johnson et al. , 2005) and (3) gather the data of the improvements achieved with these changes through research studies and scientific documentation.

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