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Right to read: what we can learn from neurosciences to augment childhood and literacy policies[1]

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Abstract

Early adverse experiences are associated with a diverse range of health and learning issues, and scientific evidence suggests that they might have a long-term impact on the developing brain. Poor socioeconomic conditions also appear to reinforce stress-inducing experiences related to adversity and are connected to a disadvantageous literacy environment. There are indications that these factors play a role in early cognitive gaps in essential literacy skills that might place children in a cumulative disadvantage path in literacy and consequent academic trajectory. This literature review analyzes the effects of early adverse experiences, such as poverty, violence, abuse, neglect, and hunger, on the development of key brain areas and cognitive skills related to reading to propose policies that, following neuroscientific knowledge, can contribute to minimizing the impacts caused by such stressors on the academic trajectory of vulnerable students. Historically in Brazil, the impacts of stressors are vaguely considered in the formulation of education public policies. Understanding how such negative experiences influence neurodevelopment and seeking actions to combat them can be the key to providing healthy cognitive development and guaranteeing children's right to reading.

Keywords

Literacy – Adversity – Toxic stress – Cognitive development – Cumulative disadvantages.

1- Data availability: the data set used to substantiate this literature review are published in the article.

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O direito de ler: o que podemos aprender com as neurociências para ampliar as políticas de infância e de literacia

Resumo

Experiências adversas no início da vida estão associadas com diversos problemas de saúde e de aprendizagem, e evidências científicas sugerem que elas podem ter impacto de longo prazo no cérebro em desenvolvimento. Condições socioeconômicas precárias parecem reforçar experiências indutoras de estresse e estão conectadas a ambientes desfavorecidos em termos de linguagem. Há indícios de que tais fatores sejam preditores de defasagens em habilidades cognitivas essenciais para o aprendizado da leitura e da escrita, podendo colocar as crianças em caminhos de desvantagens cumulativas em relação à alfabetização e consequente trajetória acadêmica. Nesta revisão bibliográfica, foram analisados os impactos decorrentes de experiências adversas no início da vida, tais como pobreza, violência, abuso, negligência e fome, no desenvolvimento de áreas cerebrais e de habilidades cognitivas essenciais à leitura para propor políticas públicas alternativas que, à luz dos conhecimentos neurocientíficos, possam contribuir para minimizar os impactos causados por tais fatores estressores na trajetória acadêmica de estudantes em situação de vulnerabilidade. Historicamente, no Brasil, os impactos dos fatores estressores são considerados vagamente na formulação de políticas públicas educacionais. Compreender a influência de tais experiências negativas no neurodesenvolvimento e buscar ações para combatê-las pode ser a chave para proporcionar um desenvolvimento cognitivo saudável e garantir o direito das crianças à leitura.

Palavras-chave

Letramento – Adversidade – Estresse tóxico – Desenvolvimento cognitivo – Desvantagens cumulativas.

Introduction

Fundamentally, learning how to read is the most critical piece of academic knowledge any child might acquire, being the driving force behind their learning experience throughout their entire lives. Reading opens a path for broader learning, from understanding the news, learning their fundamental rights, to participating as active members of our society. Guaranteeing children's right to read is critical to reduce social and educational disparities and provide equal opportunities. Throughout school, children with better early-reading skills will read more, outperform their peers in literacy tests, and acquire broader knowledge in different domains throughout their lives (CUNNINGHAM; STANOVICH, 1997; LONIGAN *et al.*, 2013; STANOVICH, 1986).

Human development does not happen independently from social and biological factors (BRITO; NOBLE, 2014). The interplay between these factors in human life has deep connections. It plays a fundamental role in learning new social and cognitive skills, as biological development is heavily embedded in early experiences (SHONKOFF, 2010). The precise mechanisms of how the sociological and biological aspects of learning work together need to be further researched. In the past four decades, a substantial amount of data has been published on the many relationships between cognitive skills and reading, the neurobiological bases of reading, the effects of the interplay between genetics and cultural background, and how adversity affects the developing brain. This new evidence presents how children learn to read and write and what stands in their way. Although governments have been using social sciences research to develop literacy and early childhood policies with reasonable success, the growing body of evidence in brain science can properly direct and further develop public policies toward more suitable approaches for early childhood development, which, in turn, can result in long term benefits for the developing youth (SHONKOFF, 2010).

In Brazil, literacy policies formally start in elementary school, and literacy focuses on the first and second years of a child's education in any school (BRASIL, 2017). However, evidence suggests that there are differences between good and poor readers as they enter elementary school, meaning that the challenges poor readers face began even before they were enrolled (BIEMILLER, 1977-1978, CUNNINGHAM; STANOVICH, 1997; STANOVICH, 1986). As such, formal schooling can only account for some of the disparities that can be found between those students later. Additionally, the overall academic achievement gap between poor and good readers widens as they progress, as good students get even better, and poor students fall far behind.

In this context, understanding the differences present before students begin their formal schooling process and how to address them is paramount to reduce educational gaps. Some of these differences between good and poor readers appear to have their origins in adversity, a broader term for any experience or circumstance that might pose a real or perceived threat or burden to children, such as poverty or violence (SHONKOFF, 2012). These early adverse experiences appear to influence the development of brain structures required for reading. Adversity itself is inherent to human life, but if it manifests repeatedly and over long periods, the high levels of cortisol and other hormones produced by the human body due to stress responses might cause underdevelopment of brain areas (SHONKOFF, 2010; SHONKOFF *et al.*, 2012).

This paper reviews the literature from three different areas: medical, cognitive psychology, and educational, connecting these academic productions to shed light on which social and biological mechanisms are at play before and at the start of formal schooling that influences early reading and, therefore, should be accounted for by policymakers when thinking about literacy policies. By understanding the underlying biological mechanisms related to early adverse experiences and the cognitive skills required for children to learn to read, policymakers can adequately address the causes of underachievement in literacy before children enter school, protecting the developing brain and not only stimulating them but also creating better and positive early literacy experiences.

Background: a brief overview of literacy research

Literacy is a critical skill in academics and life, but early childhood literacy research is recent (GILLEN; HALL, 2003). Many early studies focused on reading, specifically, as being isolated from its environmental settings and as a strict schooling process. Early research also focused on physical aspects of reading, such as eye movement, pauses, and visual perception (MARTIN *et al*., 2012). Only later in the last century, research in early childhood literacy that observed individual children (BAGHBAN, 1984; CRAGO; CRAGO, 1993; PAYTON, 1984; BISSEX, 1980 *apud* GILLEN; HALL, 2003), and a broader number of children (CLAY, 1975; MASON, 1980; HIEBERT, 1981; HARSTE *et al*., 1982; SULZBY, 1985 *apud* GILLEN; HALL, 2003), pointed that literacy should be reevaluated as more than simply reading and writing that begins at school: it should be observed as a continuum that begins earlier and continues throughout the individuals' lives.

Also, in this period, with the rise of sociocultural theoretical perspectives on learning, research in literacy shifted, observing the interplay between families, school, communities, and their cultural backgrounds, and understanding literacy as more than reading and writing, but rather a cultural and contextual phenomenon (MARTIN *et al*., 2012). This shift appears to be highly influenced by later translations of Vygotsky's work, which suggested that children first observe the language around them and then use it (GILLEN; HALL, 2003). As such, the concept of literacy as a social practice is still dominant in research. In this movement, inspired by the Whole Language theory – one of many constructivist approaches to literacy –, Frank Smith (1971 *apud* SOARES, 2018) proposed that learning to read was a natural process. Children, in his theory, would naturally learn to read as they learn to speak. The spark of this new theory spread worldwide and inspired others to propose a "no method" method of teaching to read (SOARES, 2018). Frank Smith's theory is highly disregarded today. Stanovich (2000) states that his proposal "is not considered true by any linguist, psychologist or cognitive scientist" today. His theory disregards that almost all human communities have developed some sort of spoken language; however, only a few have developed written language. Written language is also recent in human history, being developed only 5000 years ago, whereas the alphabet is approximately 3800 years old (DEHAENE, 2007). Although children do learn from their social experiences, Smith failed to account that this appears to be only a part of the picture (DEHAENE, 2007; STANOVICH, 1986). While it seems culturally natural to learn to read and write, there is no specific area of the brain capable of processing it, but a set of circuitries that support each other in the complex cognitive task of reading and writing (DEHAENE, 2007). Moreover, language development begins before birth, as children first hear speech patterns from their parents, and is a constant interplay between environmental factors and genetically determined factors (MINAI *et al*., 2017).

In the past four decades, research in literacy has been trying to find and account for different biological and sociological variables for how children learn to read and write. In the 80s and 90s, substantial amount of evidence was produced on individual cognitive skills in reading and their relationship with each other (CARR, 1981; DE SOTO; DE SOTO, 1983; MITCHELL, 1982; PALMER MACLEOD; HUNT; DAVIDSON, 1985; SHARE *et al*.,

1984; SINGER; CROUSE, 1981; STANOVICH, 1982a, 1982b, 1986 *apud* CUNNINGHAM; STANOVICH, 1997; STANOVICH, 1986), creating a solid case for phonemic-based approaches towards literacy. While it is essential to pinpoint the cognitive skills required to read and write and create a conceptual and analytical framework in linguistics, this model still failed to account for some genetic and environmental factors.

Research shifted again as brain scanning methods became accessible in the 90s and 2000s. Brain science has been filling the gaps in how cognitive skills correlate with specific brain areas and how those areas are affected by the interplay between early experiences, cognitive skills, and biological factors. For instance, stress, poverty, family education, and hunger affects the cognitive skills required for reading, such as phonological awareness, print exposure, and word recognition (BRITO; NOBLE, 2014; NOBLE *et al*., 2006).

Governments around the world have been able to incorporate evidence from social sciences into literacy policies with reasonable success in the past decades, as shown by increases in the literacy scores in standardized tests, such as the Program for International Student Assessment (PISA), and how the overall literate populace in the world is steadily increasing (SHONKOFF, 2012). Nevertheless, in the past two decades, with the advances in neurosciences, new findings present new reasons why children fail to learn to read. Those findings should be incorporated into literacy policies as well.

Data and methods

The studies were selected based on their availability in either English or Portuguese language. The authors made no distinctions regarding geography. Given our goal of providing quality information to inform public policy, the strategy for selection was that of relevant publications in the field. The papers selected, unless otherwise perfectly matching other selection criteria, should be well-referred by the academic community. All works reviewed had at least 500 citations, but most had over 3000 from Google Scholar. We attempted not to discriminate publications from specific journals, as there was no obvious advantage in restricting an already restrictive search. Different strategies were employed for each sub-area of exploration:

Medical papers were included if: (a) they reported self-collected data on the relationship of adversity, broadly defined as a real or perceived threat or burden, and (b) children's brain development. The search targeted studies that collected data from brain imaging, associating the results with adversity and reading acquisition. Given the scarcity of such papers, other brain imaging research associated with reading and literacy were explored.

Cognitive Psychology and Education papers were included if: (a) they performed longitudinal studies on literacy acquisition and/or achievement, and (b) came from the literature on individual differences in reading, in line with the medical literature analyzed. While there is ample literature on reading acquisition, most focuses on children with special needs or doesn't observe individual differences.

Key terms used for the exploration of papers involved: "Toxic Stress" or "Adversity" or "Trauma" or "Poverty" or "Socioeconomic Status" AND "Reading Acquisition" or

"Reading" or "Literacy" AND "Brain Development" or "Neurosciences" or "Brain scanning" or "fMRI" .

A total of 87 papers were selected from this web search based on abstracts and apparent relevance to our study. The 87 papers were skimmed and selected using the above criteria. Finally, 31 papers were selected for their relevance in the field, and capacity to explain the phenomenon we aim to describe: how adversity impacts children's reading acquisition. Papers were thoroughly analyzed, and their findings are discussed in the following sections.

Our study diverges from systematic literature review papers by outlining research results in the context of a larger discussion about the state of literacy policies. Systematic literature reviews on each of those areas already exist and our goal was to fill a gap in translating said research into a policy context. We also chose a more fluid narrative to accomplish that.

How children learn to read: what we know today

There is no specific area in the brain dedicated to reading when children are born. It is hypothesized that children slowly recycle their neurons from already functional visual and linguistic circuitries in the left occipital-temporal region to acquire literacy skills (DEHAENE, 2012). Children slowly develop and specialize in this area from birth and then connect it with other parietal, temporal, and frontal regions. This process occurs by contact with print, reading from their parents and teachers, and learning the basics of the alphabetical principles as they grow older. Brain images from babies aged 2 and 3 months already present localized linguistic skills in the left hemisphere. From 6 to 12 months, babies will develop specialized areas for vowels and consonants and create a basic sense of standard phonetical strings in their native language. By age 2, children's vocabulary will start to grow, and the first grammatical principles will be attained. By the age of 5 or 6, children will already have a substantial vocabulary and a basic implicit understanding of the grammatical structure of their language (DEHAENE, 2012).

In the early stages of reading, children still do not understand the rules and logic of the written language and will play with words as if they were pictures. This pictorial phase is reflected in brain activation, as illiterate children activate the right occipital-temporal region, a brain area known for recognizing faces and objects (DEHAENE, 2012; SOARES, 2018). Children do not correctly decode text at this stage but might be able to guess words based on their shape. In a secondary stage, children will be required to develop the most basic alphabetical principles: the ability to manipulate individual sounds or phonemes. In time, it is expected that children will start to decode text into sound, grasping the phonemic and graphemic code together. The ability to manipulate and map print to sound aspects of language is defined as phonological awareness (STANOVICH, 1986).

There is substantial evidence that Phonological Awareness is the primary mechanism that enables early reading success. This is well documented in research (BRITO; NOBLE, 2014; CUNNINGHAM; STANOVICH, 1997; DEHAENE, 2007; JOHNS *et al*., 2018; LONIGAN, 2013; NOBLE *et al*., 2012a, 2012b; STANOVICH, 1986; STANOVICH; CUNNINGHAM; CRAMER,

1984; STANOVICH; CUNNINGHAM; FEEMAN, 1984a, 1984b). Preliterate children (those who have yet to enter formal schooling) with better phonological awareness learn to read faster; however, kindergarten phonological awareness predicts teenage reading ability better than kindergarten reading skill does (CUNNINGHAM; STANOVICH, 1997; NOBLE; TOTTENHAM; CASEY, 2005).

As children learn to decode text into sound properly, brain images show that activation shifts from the right occipital-temporal region to the left occipital-temporal region, precisely where it is observed in literate adults (DEHAENE, 2012). Two other regions appear to develop simultaneously, the superior temporal sulcus and the inferior prefrontal cortex, the Broca area, composed of the pars triangularis and pars opercularis. Both regions are linked to language processing and comprehension (DEHAENE, 2012; JOHNS *et al*., 2018). With the proper development of these areas, children will more easily decode and acquire more vocabulary. Vocabulary itself appears to have dedicated brain areas. Children will access words in the first stages of reading by manipulating print to sound patterns. Then, when a word is acquired, they access it directly, without using a phonological route. This process makes word recognition and text decoding automated and less resource-demanding (STANOVICH, 1986; STANOVICH; CUNNINGHAM; CRAMER, 1984; STANOVICH; CUNNINGHAM; FEEMAN, 1984a, 1984b). In turn, children will be able to reach for more cognitive intensive processes, such as text comprehension.

Matthew effects on education: what happens when children fail to read

Stanovich, Cunningham, and Feeman (1984a, 1984b) and Stanovich (1986) elegantly used the term *Matthew Effect* in education to describe the "rich-get-richer and poor-get-poorer" mechanisms rooted in the social experience of literacy for children in the context of cumulative advantages or disadvantages in education. With the reading acquisition process in mind, a child's difficulty in overcoming the first barrier in literacy, turning print into sound effectively, might escalate into several issues in later academic achievement (BIEMILLER, 1977-1978; CUNNINGHAM; STANOVICH, 1997; STANOVICH, 1986). Not only do children with poor early reading skills appear to fall behind, but the gaps between them and the best readers will grow wider as they progress. Children who are struggling will often be given materials that are too difficult for their current reading levels, making a first bad experience carry over, creating more significant gaps in later stages of education (STANOVICH, 1986). On the other hand, children with better print and phonological awareness will have more access to reading and knowledge, with a positive feedback loop that spans throughout their lives. They will more easily decode text, have a more extensive vocabulary, have faster word recognition skills, and will be able to access higher-level cognitive processes, such as text comprehension.

Research has found that children who demonstrate lower basic skills required to learn to read and write, such as understanding the spelling-to-sound code, would, ten years later, underperform in tests in comparison to their peers. In the long run, they would have less contact with reading than their peers and less vocabulary and read less

(CUNNINGHAM; STANOVICH, 1997). As children enter formal schooling, early gaps in emergent literacy skills might become – if not adequately addressed – deficient decoding skills, resulting in slower reading and word recognition, since they are using their cognitive resources for basic tasks instead of accessing higher-level skills, such as text integration and comprehension (CUNNINGHAM; STANOVICH, 1997; STANOVICH, 1986). Noble *et al*. (2006) also show that children with higher phonological awareness will read well, despite lower socioeconomic status.

Biemiller (1977-1978) has documented children in first grade and their ability to read words throughout their first school year. The group of abled readers averaged a mean of 12.2 words read in October, 25.8 in January, and 81.4 in April. The group with the least abled was not reading at all by October, was reading an average of 11.5 words in January and 31.6 words in April, showing that the gap between the abled group and the least abled group grew even more significant as time went by, and was present from the moment the children entered the classroom for the first time.

Northrop (2017) performed a longitudinal study with a group of students (n=7,746) from kindergarten to eighth grade and evaluated them on literacy tests. Results showed that approximately 27% of students began kindergarten without mastery of letters, and 12% maintained a cumulative disadvantage pathway eight years later. Observing specifically the 2,123 students with low achievement in kindergarten, only 54% were able to recover by eighth grade.

It is essential to notice that unsuccessful learning trajectories can be reversed (LONIGAN, 2013; NORTHROP, 2017). Teachers and policymakers should strive to identify and enhance efforts to break this cumulative disadvantage path. Nevertheless, understanding the underlying mechanisms by which children fall behind in literacy can be vital in changing how early literacy policy is made and in directing policymakers to create early life interventions to conduct children into a successful path from early on, instead of trying to remediate problems later in their educational journey.

Adversity in the developing brain: why children fall behind

Adversity is a broader term for any experience or circumstance that might pose a real or perceived threat or burden to children. It is well documented that these perceived or actual threats induce physiological responses: the activation of the hypothalamic-pituitary-adrenocortical axis (HTPA axis) and the sympathetic adrenomedullary system (SHONKOFF, 2012). The HTPA axis is a complex endocrine set of interactions and feedback between the hypothalamus, pituitary, and adrenal glands. The HTPA is responsible for stress responses and cortisol production, controlling body processes such as digestion, emotions, and energy storage. The sympathetic-adrenomedullary system is the physiological connection between the sympathetic nervous system, responsible for "*fight or flight*" responses, and the adrenal medulla, the innermost part of the adrenal gland, consisting of cells that secrete adrenaline, noradrenaline, and dopamine. In short, when the body receives threatening sensory information, it produces stress hormones, such as cortisol and adrenaline. While this process is natural and protective, and could even be considered essential for survival, when children are overexposed to stress and,

consequently, face prolonged or high-level periods of stress hormones, evidence suggests that the high level of hormones turns toxic and might cause long term damage to several body systems, including the brain (SHONKOFF, 2012; SHONKOFF *et al*., 2012). Evidence suggests that the physiological response appears to be a short-term survival strategy that creates long-term damage (SHONKOFF, 2010).

Although genetics plays a big part in stress reaction control, prenatal maternal stress and stressful early experiences might have a long-term impact on stress response (SHONKOFF *et al*., 2012). While all mechanisms that play a role in this process are still in research, there is some medical consensus that epigenetic *modifications to the DNA* and alterations in neuroendocrine circuits happen in the early stages of neural development in such cases. To differentiate these adverse circumstances or experiences from the day-to-day hardships most humans face, the National Scientific Council on the Developing Child (2005) in the United States developed a taxonomy of three categories to classify stress and how it impacts individuals: positive, tolerable, and toxic. These categories do not define the source of the stress but rather how it manifests in the subject. Poverty, violence, abuse, neglect, and hunger are some variables considered when discussing adversity in brain research in the context of toxic stress.

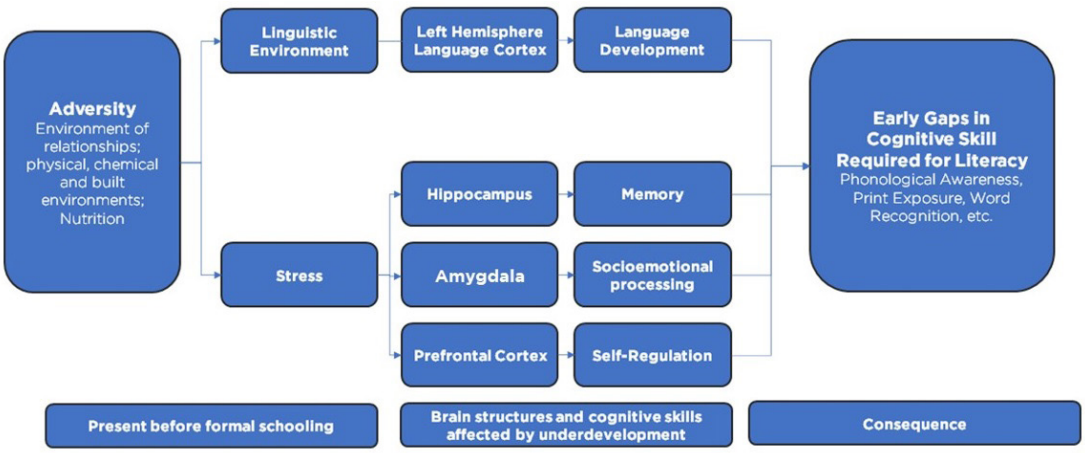
Some of the effects of toxic stress are loosely observed by policymakers and educators as behavioral problems, emotional problems, difficulty adjusting to social settings, problem focusing and paying attention, and other learning challenges. Understanding the underlying problems and why they manifest might be essential to shifting public policy to better address early learning.

Several different brain circuitries are at work when children learn to read. Even in neurotypical individuals, it would be possible to underscore several developmental impediments that could limit their ability to fully explore literacy opportunities (SHONKOFF, 2012). Children's poor reading skills appear to be due to an interplay between several non-mutually exclusive social and biological factors, and further research is necessary to define the precise mechanisms and their relationship. Still, there is some consensus in literacy research points to some of these factors: socioeconomic disadvantages (including the linguistic environment, as in lack of exposure to literacy or low-income family), stress-inducing issues (as in hunger, violence, and lack of nurturing environments and parental figures) and individual differences (high or low intelligence, stress tolerance, and other executive functions) (BRITO; NOBLE 2014; NOBLE; TOTTENHAM; CASEY, 2005; NOBLE *et al*., 2006, 2012a, 2012b; JOHNS *et al*., 2018). Most of those mechanisms can be inserted in the context of adversity. This paper has two critical factors: toxic stress and lack of a diverse and rich linguistic environment. These two factors appear to have consequences for the developing brain in specific brain areas related to reading. Lack of a rich linguistic environment appears to influence the left hemisphere and in the reading areas of the brain, and research has also shown that toxic stress appears to affect three significant brain structures: the hippocampus, the amygdala, and the prefrontal cortex (BRITO; NOBLE, 2014). Figure 1 shows an overview of those experiential differences and their downstream effects on brain structures. The figure is adapted from Brito and Noble (2014) with Shonkoff's (2010) biodevelopmental framework. In Brito and Noble (2014), the overview presents Socioeconomic Status (SES) as an origin point. Still, adversity appears

to account for a more significant number of variables, including those in SES, which influence disparity in learning and behavior.

SES is a multifaceted construct that observes different experiences, often family income, neighborhood violence, educational attainment, and occupation (BRITO; NOBLE, 2014). By itself, SES does not account for the entirety of childhood experiences, since families living in absolute poverty with low educational level can provide nurturing environments and strong literacy support (BRITO; NOBLE, 2014). Nevertheless, children in homes of lower SES appear to be less exposed to a diverse linguistic environment and are more susceptible to stress. Combined, these two mechanisms can be devastating to a child's long-term academic success by halting their abilities to become good readers early on and creating a cumulative disadvantage that they will carry throughout their lives if these are not adequately addressed.

Figure 1 – Hypothesis on how adversity operates to influence structural and functional brain development and cognitive skills



Source: Adapted from Brito and Noble (2014).

Children slowly create strategies, recycle, and specialize neuronal circuitries required for reading. The evidence suggests that this process does not happen isolated from social interactions, corroborating other social learning theories (KUHL, 2007; KUHL; TSAO; LIU, 2003; VYGOTSKY, 1991). Children from ages 0 to 2 years will gather language information from their environment and process it by themselves, making assumptions about the rules and functions of the spoken language. Experiments show, however, that only exposure to a specific language does not translate into learning. Although exposure to language material (such as TV shows) can promote some learning, children do not absorb the more complex aspects, such as grammar and phonetics (KUHL; TSAO; LIU, 2003), required to become great readers. In this sense, evidence suggests that language acquisition is driven by social interactions and instruction (CUNNINGHAM; STANOVICH, 1997; KUHL, 2007).

Noble, Tottenham, and Casey (2005) has found a strong correlation between socioeconomic background and word reading skills. SES usually accounts for family education, which could point out that children in lower SES homes are less stimulated by their parents' literacy. Relationships between cognitive stimulating experiences and poverty have also been documented, whether in a family environment or not (MCLOYD, 1998). Children with socioeconomic disadvantage also appear to score lower on literacy, memory, and executive functions tests (PAVLAKIS *et al*., 2015). Research has found that decoding ability and print exposure positively correlate with Grey Matter Volume in the Supramarginal Gyrus (SMG) (JOHNS *et al*., 2018). Print exposure is correlated with vocabulary knowledge (CUNNINGHAM; STANOVICH, 1997; STANOVICH, 1982a, 1982b, 1986), which might present a complementary explanation to the differences found in children from rich linguistic environments and children from poor linguistic environments (KUHL, 2007).

Evidence suggests that toxic stress will affect a child's ability to self-regulate their attention, emotions, and behaviors (BRITO; NOBLE, 2014; NOBLE; TOTTENHAM; CASEY, 2005; SHONKOFF, 2010, 2012). Prefrontal cortex development closely matches the acquisition of executive functions over time, and underdevelopment of this region could explain associated behaviors. Gianaros *et al*. (2007 *apud* BRITO; NOBLE, 2014) observed that lower subjective social status (how one identifies their social standing on a specific group) is associated with reduced grey matter volume in the anterior cingulate cortex, a brain area often related to attentional processes and self-control.

Research has also found a substantial relationship between grey matter thickness in the suitable frontal/parietal regions with print exposure, working memory capacity, phonological awareness, comprehension, and decoding ability (JEDNORÓG *et al*., 2015; JOHNS *et al*., 2018). Some literacy skills also appear to be related to the pars opercularis in the left inferior frontal gyrus. Grey matter thickness and volume in the left inferior frontal gyrus also correlate positively with children's phonological awareness. These areas appear to be compromised in children from lower socioeconomic backgrounds. Evidence suggests that adults with poorer literacy skills have less grey matter volume in the left supramarginal gyrus, part of the left parietal lobe, and left inferior frontal gyrus (pars opercularis) (JEDNORÓG *et al*., 2015; JOHNS *et al*., 2018).

Conclusions and policy implications

Current brain research has several challenges and limits in connecting structural and functional images to cognitive outcomes. Bridging the anatomical, physiological, and behavioral aspects of development will be a breakthrough for understanding how learning happens in the brain. Nevertheless, by observing what happens to children before they enter school, current findings already present alternatives to common misconceptions about why children fail to learn to read. They shed light on an aspect that has been deeply researched in social sciences: children who experience severe hardships for long periods have more problems as they grow up. These problems range from health issues (heart disease, higher risk of diabetes, shorter life spans, and other inflammatory diseases) to learning issues (self-regulation, inhibitory control, attention), which might create

cumulative disadvantages processes in the long run. Policymakers often believe that by improving the schooling system exclusively, they offer children equal opportunities. The evidence presented in this paper challenges this assumption; it offers an alternative view that some children enter school already behind, and not all of them can recover, even with proper schooling, making intervention during early childhood much more critical. Therefore, it is essential to protect the developing brain, not only stimulate it.

Children from vulnerable backgrounds are especially susceptible to early adversity and, in turn, to toxic stress. They will also experience poorer linguistic environments at home. The interplay between lack of a diverse and rich language experience in early childhood and overexposure to adversity needs to be further researched; combined, these two factors account for a significant range of challenges that define why children fail to learn to read. They are correlated to the underdevelopment of specific brain areas related to reading. Furthermore, children with early deficiency in literacy-related cognitive skills, especially phonological awareness, appear to face more challenges in their educational path and underachieve in the long term.

Since it is not currently possible (nor necessary) to assess every child's brain development using scanning methods, governments should also observe and track broader and more accessible options to identify clues that might predict children's academic success, such as socioeconomic status and early literacy outcomes (NOBLE; TOTTENHAM; CASEY, 2005).

Historically, researchers and policymakers have assessed readiness and development through comprehensive achievement tests (NOBLE; TOTTENHAM; CASEY, 2005). This is problematic because children failing the same standardized tests might do so for entirely different reasons. With new evidence, readiness can be assessed by specific brain functions, identifying the biological mechanisms at work, and by the interplay between environmental and genetic factors for each child, allowing educators and policymakers to propose specific interventions (NOBLE *et al.*, 2013). Furthermore, some children enter school with disadvantages that will only manifest and be evaluated when they are already at a cumulative disadvantage. In Brazil, for instance, literacy evaluation is only performed in the second year of elementary school. At that point, the research reviewed indicates that children with reading issues are already falling behind. Educational assessment policies must consider this evidence when defining the assessment of children's literacy.

Educators must also understand literacy as a process that starts before elementary school. Children are not suddenly ready to read when they turn six years old. The development of the brain areas related to reading depend on both social interactions and instruction, which are equally paramount to their full development. Kindergarteners with better phonological awareness will outperform their peers, indicating the importance of creating an early understanding of basic alphabetical principles and acquiring basic cognitive skills. Expanding kindergarten and preschool access to allow parents from lower SES backgrounds to provide a more prosperous linguistic environment is also relevant. Kindergarten and preschool teachers should have in mind that they must create such environments to help parents with less educational attainment develop their child's emergent literacy skills.

Finally, policymakers should also take an intersectoral approach towards early childhood and literacy based on the findings presented. Different agencies usually undertake hunger, violence, health, and education issues. An intersectoral approach to the problems is necessary if governments intend to address all causes and create healthier and nurturing environments for children, ones that promote their growth and learning. Addressing adversity is critical to reducing inequalities in education, requiring a network of support since schools by themselves cannot address all problems related to adversity. Governments must support the most vulnerable families so that the children can thrive. Given the correlations between a population's educational level and economic development and the evidence regarding the importance of early literacy skills for academic achievement and cognitive development, guaranteeing children's right to read might be a pivotal factor for long-term national development.

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