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Atypical development and the cultural background underlying neurological maturation

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Learning, attention, hyperactivity, and autism spectrum disorders have common neurological roots. They are manifested in differences in the development and functioning of the neurological processes involved in neurological maturation. Neurological maturation is a product of the cultural evolution of Homo Sapiens. The transition to an agricultural, ranching lifestyle required behavior and cognitive functions that were markedly different from the previous foraging, nomad lifestyle. The result was a more precise and reliable ability to control and think systematically, which later became the base of literacy. The recent spread of learning difficulties, control disorders, and autism spectrum are due to the vulnerability of brain functions that are very new to human development, most of all executive functions. There are significant changes in culture since the last century, whereby the developing nervous system receives less natural cultural developmental effects but more harmful agents than before. Changes in the environment change the way the brain develops. Atypical neurological development is a consequence and a sign of a new era. It is only considered a disorder if education fails to find an appropriate response to the challenge.

Keywords: atypical development, learning, attention, hyperactivity, autism disorder spectra, neurological maturation, digital age

Introduction

The human nervous system develops in interaction with environmental influences and therefore both reflects and adapts to any changes in the environment. The accelerating change in technology (and info-communication technology in particular) has an exceptionally large influence on humanity's social-mental functioning. These factors have an even more significant influence on the neurological development of small children. What underlies the increasing rate of diagnoses in learning, attention, hyperactivity, and autism spectrum disorders is a neurological response to environmental effects. Neurologically-based performance disorder – i.e., atypical development – is an indicator that points to the incompatibility between children and the systems of education and development. Currently called disorders, syndromes that are responsible for performance issues that might not always be apparent can be construed as

an evolutionary response to environmental factors. The flexibility of the human nervous system, neuroplasticity, comprises the brain's immense capacity for renewal, regeneration, and compensation (Merzenich, 2001). In a child's nervous system, altered cognitive functioning is a response to environmental factors and does not only manifest itself in performance disorders, but also in results that are different from the usual or even exceptional in some cases.

Atypical development

Dyslexia, dysgraphia, dyspraxia, dyscalculia, and attention, hyperactivity, and autism spectrum disorders have been thoroughly proven to be rooted in shared neurological exceptionalities, a fact that is also indicated by their highly frequent co-occurrence in various combinations. According to studies by Richardson and Ross (2000), the reason for this frequent comorbidity lies in abnormalities in the production of fatty acids that play an important role in neural transmissions within the brain.

Movement planning and coordination, sequentiality, and the ability to keep rhythm and time are all problem areas in the case of learning disorders, attention disorder, hyperactivity disorder, and autism spectrum disorders alike (Denckla et al., 1985; Schonfeld et al., 1989; Barkley et al., 1997; Greenspan & Wieder, 1999; Piek et al., 1999). According to Pauc (2005), these co-occurrences are so frequent that the symptoms could in fact be jointly identified as delayed development syndrome.

Atypical development does not affect the entirety of an individual's mental ability: the area of deviation can be clearly delineated and lies in the field of neurological harmony and maturation. At least three mutually independent systems are at work through the course of cognitive performance. Although these systems are independent in terms of neurological functioning, all of them play a role in cognitive performance. Any deficiency or disorder found in any one area will manifest as a cognitive disorder. The following three factors comprise mutually independent units of key importance in cognitive functioning:

1. The maturation of the nervous system, the individual characteristics of the neurological system, typical or atypical neurological functioning.
2. Intelligence, the level of efficiency in thinking and learning.
3. Abilities (linguistic, musical, visual, kinaesthetic, etc.), the foundations for thinking and learning that form a system of abilities specific to the individual.

Atypical development affects specific parts of the cognitive system and is independent of intelligence and ability areas, although high intelligence and outstanding abilities in a specific area offer opportunities for compensation.

Forms of atypical development

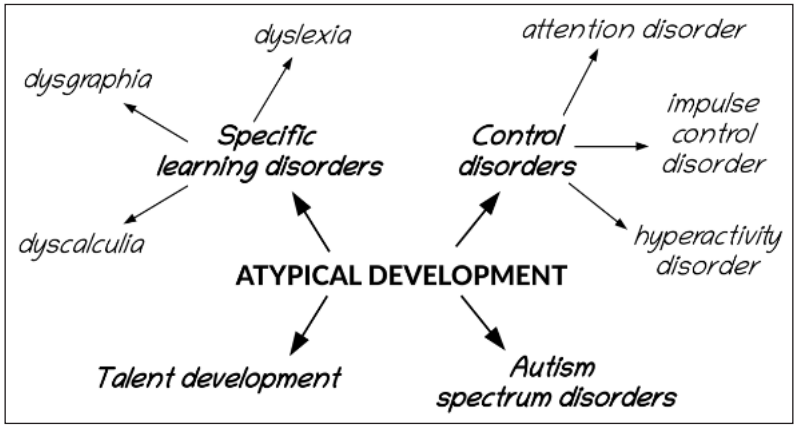
The shared neurological exceptionalities that underlie different forms of atypical development determine the core of the syndrome. At the same time, other internal and external factors can result in different combinations and intensity

patterns of cognitive deviations in reading, counting, literacy, attention and behaviour control, the concreteness of perception and information processing, and outstanding cognitive performance. The following characteristics apply to all forms of atypical development:

– it is rooted in a different-from-normal neurological functioning;
– it has both advantages and disadvantages throughout the individual's lifetime;
– it is independent of intelligence;
– it is environment-dependent.

The final item explains why changes in the twenty first century have had a particularly significant effect on the occurrence of atypical development. Increased prevalence owing to environmental factors has brought each of these exceptionalities, along with their study, into the spotlight. The final item in the list also entails the factor that atypical development can be readily influenced by shaping the environment – that is, through early development and appropriate education.

Figure 1
Forms of atypical development



Other than performance disorders, a neurological system displaying atypical development can also produce advantages in performance, that is, some evolutionary benefit can be associated with exceptionalities. Together with the fact that exceptionalities diagnosed as disorders often co-occur with both one another and talent development, the presence of shared neurological processes underlying all of them indicates mutually overlapping developmental exceptionalities. Characteristics associated with performance disorders occur with high frequency among the features associated with talent and giftedness. Examples include an efficient management of spatial-visual wholes, the ability to abstract (primarily characteristic of learning disorders), a strong associative disposition (mainly characteristic of attention disorders), low tolerance of monotony, quick reactions (primarily characteristic of hyperactivity),

methodical thinking and perseverance (characteristic of autism disorder). In many cases, not even professionals are able to decide which forms of atypical development (or possibly talent development) intertwine in an exceptional child (Gyarmathy, 2009).

The neuropsychological background underlying the culture of literacy

Thom Hartmann (1995) hypothesises that individuals diagnosed with attention disorder are descendants of the hunter *Homo sapiens* and are characterised by modes of information processing and responses that are different from those who turned into farmers and now form the majority of humanity. By now, Hartmann's hypothesis has been supported by other study results. What is more, this insight might also apply to learning and hyperactivity disorders.

While its relevant behaviour and associated cognitive functioning might now be considered a disorder, these phenomena had definite advantages in early human cultures. In fact, for millions of years, the human neurological system used to be optimised toward the hunter-gatherer lifestyle. The mode of perception and actions of hunter-gatherers are characterised by the following:

– spatial, visual, impulsive, cooperative
– acquires rather than stores
– looks for, finds, selects
– searches, explores, gathers, moves along
– guesses, imagines, intuits
– risk-taking and trial-and-error.

It was only approximately ten thousand years ago that a form of functioning emerged that rendered the human neurological system suitable for the lifestyle of agriculture and husbandry. In other words, from a neuro-evolutionary point of view the mode of perception and activities that make husbandry possible is quite recent and characterised by the following traits:

– temporal, fixed, controlled, sequential
– sows, tends, harvests, stores
– foresighted, economical, methodical
– the work is tied to a place and organised
– plans and implements methodically
– thinks systematically

As can be seen, the features that enable the methodical, planned type of work suitable for an agrarian lifestyle are virtually the opposite of the neurological functioning necessary for a nomadic way of life. Individuals whose neurological system had become suited to agricultural activities would have gained a significant evolutionary advantage. The agricultural-animal breeder lifestyle is much steadier, more certain and far more efficient compared to the hunter-gatherer lifestyle. This change is basically what set humanity on the path toward a rapid development that in turn led to significant socio-cultural changes.

Rooted in the neurological functioning that developed together with agriculture, the culture of literacy is suitable for controlled, planned, and methodical activities. In itself, reading and writing – i.e., 'literacy' – is the application of agriculture, that is, a type of methodical and rhythmical work that occurs at the fine motor level. All of these processes are made possible by stronger executive functions. The development and school education of children precisely target these modes of functioning; disorders in learning and control functions can be attributed to an instability in the area of these executive functions.

Precision tools that can be linked to the prefrontal areas of the cortex in the human brain, executive functions are thus the product of a cultural era in which success, and even survival, was largely determined by an individual's ability to maintain self-control, carry out activities with precision and in a controlled way, and remain attentive in the course of task performance. What we are discussing is a relatively new neural functioning package, one that is only a couple thousand years old and which humanity has consciously attempted to pass on to successive generations through developmental activities. Sports, juggling, Eastern movement arts, arts in general, strategic games, etc. are all tools of culture that work toward 'cultivating' the brain (Gyarmathy, 2012). The term 'cultivation' is also used to describe the cultivation of land, yet also signifies the preparation of the brain for methodical activities. (It is no coincidence that the word 'culture' has taken over from its Latin counterpart a dual use containing both an agricultural meaning and a more abstract, metaphorical one that originally refers to the cultivation of the mind.)

In the twenty-first century, the culture of literacy is being taken over by the culture of info-communication and technology. As a result, the development and role of executive functions is undergoing a fundamental change. Rather than signalling some random decline in the abilities of masses of children, the increasing prevalence of performance disorders is a sign of this shift.

The role of executive functions in the emergence of performance disorders

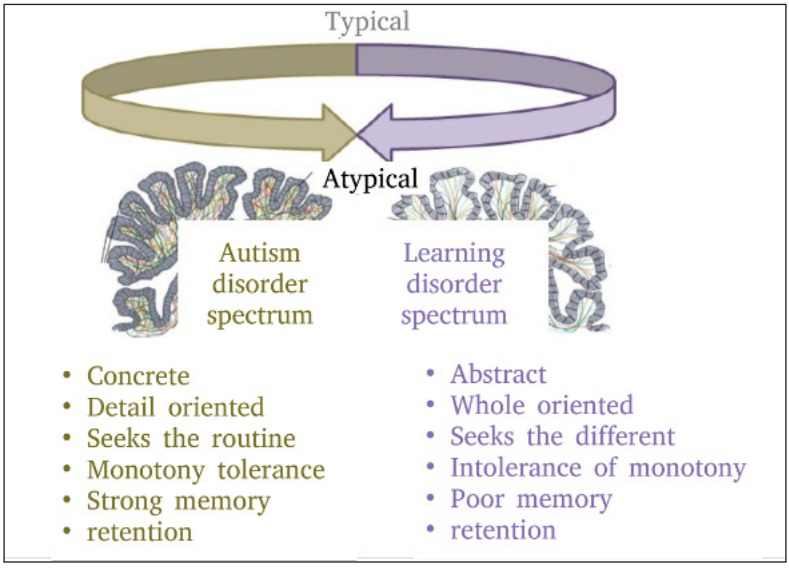
A neuropsychological umbrella term, 'executive function' refers to behaviour planning, maintaining activities and goals, controlling impulses, ordering the elements of an activity and inhibiting them as necessary, monitoring a process, and maintaining and focusing attention. All of these functions comprise indispensable cognitive processes for methodical work: a disorder in these areas is definitive in the development of neurological performance disorders. Learning, attention, or hyperactivity disorders are typically characterised by a weakness and underactivity in most executive functions. In the case of autism, difficulties originate in the overactivity of certain functions.

Thus, in several respects we encounter opposite problems when it comes to the different groups of developmental disorders – the learning disorder spectrum versus the autism disorder spectrum – in atypical development. Still, experience shows that autism disorder can also be accompanied by dyslexia,

dyscalculia, attention, and/or hyperactivity disorder. As has been remarked above, studies have confirmed that the very same biochemical and brain physiological deviations can be identified in all forms of atypical development, including autism spectrum. This commonality only appears contradictory if we treat the two types of atypical development as mutually independent spectrums. In fact, discussing two separate spectrums is not possible since developmental disorders are caused by disorders in the exact same neurological functions. A system is overturned both when it is underactive or overactive, resulting in something different from normal – in this case, atypical cognitive functioning.

MRI studies also confirm that a continuum can be identified, at the opposite ends of which learning disorder and autism spectrums can be found. Although these disorders are embedded within the very same system, they lie in different directions (Williams & Casanova, 2010). To simplify the issue slightly, it could be said that those on the learning disorder spectrum are characterised by a hunter-gatherer type of information processing while those on the autism spectrum comprise the extremely good "farmers". From the perspective of the school system, autistic individuals actually count as good learners. Although they possess exactly the qualities that a school wants, their strong sense of rules and memory renders them inflexible and incapable of change while their partiality to monotonous tasks makes them almost caricatures of the good pupil. Controlled by inflexible executive functions, such overregulated behaviour is as atypical as a weak executive system is. Still, a high-functioning autistic individual is more ideal at school compared to the exceptionalities belonging to the learning disorder spectrum.

Figure 2
Typical and atypical spectrums



Yet, as the layout in *Figure 2* suggests, atypical development does not simply appear on either one end or the other of the cognitive spectrum. Instead, it appears on one and the same end, where, owing to unstable functioning, it can move from one extreme to the other. For this reason, the characteristics of the two spectrums often mix and combine and a learning, attention, and/or hyperactivity disorder can appear even in the case of autism. In many cases, even professionals are at a loss as to how a specific case should be categorised. As such, it can be stated that atypical development is atypical even in terms of its diagnosis. In contrast, there are no extremes in the spectrum of typical functioning, not even when the mode of information processing shifts a bit in one direction or the other. This slight shift only determines the cognitive style and does not entail exceptionality or cause a disorder because the functioning remains stable.

Neurodiversity and education

According to the definition of neurodiversity, atypical brain development is rooted in natural human differences (Jaarsma & Welin, 2011) and has profound significance for the survival of humanity. The culture of literacy was based upon the emergence of strong executive functions, a form of neurological functioning that counted as atypical ten thousand years ago. The success of this change is demonstrated by the fact that this mode of functioning has come to be viewed as typical. It therefore follows that a new cultural change can once again bring about alterations in the area of neurological functioning. Non-typical development is either reinforced by environmental factors or not: the way society handles differences, however, definitely possesses enormous significance. Since they could be signs of a new direction in development, differences and deviations that are becoming increasingly more frequent in a changing culture warrant particularly close attention.

Reading, writing, and counting constitute knowledge stemming from a form of neurological functioning that is necessary for an agricultural lifestyle; most of our info-communication activities are based on these 'school' skills. In addition to targeting the acquisition of skills, schooling also prepares children for methodical work. An agricultural lifestyle requires a brain that

– is able to carry out routine tasks,
– knows the process beforehand and plays safe,
– is characterised by vast professional knowledge as its forte.

In contrast, in the ancient hunter-gatherer culture, the kind of brain that proved useful to humanity for hundreds of thousands of years was one that

– is ready to solve tasks arising from situations on the spot,
– can adapt to an unknown future,
– is characterised by problem-solving ability as its forte.

For the purposes of attaining any kind of achievement, it is best to have access to both kinds of thinking; how much of each is needed changes somewhat by task. For example, for a hunter-gatherer lifestyle, the latter approach is the more efficient one, while the former is more effective when breeding animals.

Among other factors, this difference is where cultures differ from one another. In the twenty first century, progress in info-communication has reached a level that is leading to a cultural change. In the age of literacy, knowledge had to be sown, grown, harvested, and stored just like crops. In the info-communication age, it has become possible to acquire information by picking, gathering, and 'hunting' for it while rapid changes require individuals who are suited to solving problematic situations. Those who are capable of this will be more successful compared to those who continue to follow the lengthy process of simply producing and storing knowledge. In other words, an earlier, more ancient mode of functioning has once again become useful, merely not in the way its original form was manifested.

The role of harmful biophysical and biochemical effects

The development of the neurological system is not only influenced by the mental environment. The brain is affected by a number of biophysical and biochemical environmental stimuli which can alter the developmental processes. Mild traumas to the brain before, during or after birth, premature birth, physical impacts like head injuries, or illnesses often result in a certain amount of change in the nervous system that is not very deep, yet is overarching and specifically affects the executive functions. It is no coincidence that these effects have long been shown to contribute to learning, attention, hyperactivity, and autism spectrum disorders. The term 'minimal cerebral dysfunction' (MCD) reflects this phenomenon. Indeed, MCD signifies nothing more than a small deviation in brain functions, meaning that the maturation of the nervous system somehow did not follow the usual path.

Brain functions that are newer from an evolutionary point of view are less stable and can therefore fall more easily victim to harmful environmental effects. As was previously stated, the innovations related to the 'agricultural brain' count as very new ones from an evolutionary perspective. In the twenty first century, there has not only been a proliferation in access to information, but also in harmful effects to the brain. Chemicals against which the human defence system could not have been prepared pass through the blood–brain barrier and affect even fully developed nervous systems. These factors influence, alter, and mix up the development of small children at a far more exponential level of severity.

Even if it cannot be precisely known in every case of chemicals, drugs, cleaning products, additives, petrol fumes, lead, etc. what kinds of effects each will enact upon the developing nervous system, we do know that these substances will affect it. For some time, research results have already confirmed the connection between foods containing various synthetic materials and developmental disorders (e.g., Feingold, 1974; Healy, 1990). According to Campbell-McBride (2004, 2010), antibiotics harm the normal gut flora and substances produced by the abnormal gut bacteria start poisoning the brain already from early infancy. This 'Gut and Psychology Syndrome' could be contributing to the emergence of learning, hyperactivity, attention, and autism

spectrum disorders, as well as to depression and schizophrenia. Abnormal gut flora has been shown to increase the risk of developmental disorders in children with a propensity for these spectra (Ward, 2001).

Mobile phones and other radiation sources, along with electronic gadgets that induce magnetic and electronic fields, all affect brain development (e.g., Cotgreave, 2005; Ferreri et al., 2006). There are individuals in whom even slight exposure to magnetic and electronic fields can lead to significant changes in brain functions while no effect at all is detected in others.

The interaction of genetic and environmental factors plays a role in the emergence of atypical development. Although no single element can explain this multi-factor exceptionality, researchers have found clear connections to several harmful effects, including

- industrial pollution
- urban environmental pollution
- mercury, lead, manganese, and other chemicals
- antibiotics, drugs
- synthetic chemicals, phthalates used in the production of PCB, PFC and PVC – found in water, soil, air, and food alike
- copper, zinc, iron, folate, and omega-3 deficiencies
- electronic media
- strong and constant stress and traumas.

While the aforementioned phenomena can all be triggering factors (Lewandowski et al., 2009; Becker, 2010; Leslie &Koger, 2011; Froehlich et al., 2011; Matsuzaki ET AL., 2012; Yoshimasu et al., 2014), individual susceptibility is determined genetically. Consequently, diverse harmful effects do not influence the development of all children equally. Different levels and forms of disorders can emerge during the maturation of the nervous system as a function of, among other things, individual neurological characteristics. One child may be more likely to develop a learning disorder, while another child may be more prone to autism spectrum disorder.

Atypical developmental is a deviation in neurological maturation

Owing to the change in culture, natural diversity and the extreme plasticity of the brain (combined with the prominent role the latter plays in adaptation) is becoming increasingly more apparent owing to the increase in stimulus and information richness that has reached consummate levels by the twenty first century. In the info-communication age, children have far more opportunities to explore the information space and satisfy their interests within this environment. For children possessing outstanding intelligence, this access presents an extreme opportunity for development. At the same time, activities that prepare a child for literacy have fallen into the background. Less reading aloud occurs while more moving pictures are seen. Less active music-making takes place in favour of more listening of music. Fewer physical, bodily experiences occur in comparison to more mental experiences. As a result, children's development is becoming unbalanced. While their intelligence

and knowledge may even develop at a faster rate than before, deficiencies in important areas of ability may also arise.

The emergence of increasingly more highly developed technological tools and especially the advent of info-communication technology has transformed everyday life in the following ways:

– children are surrounded by a huge amount of experience and a large number of stimuli, so they can pick and choose;
– the brain is subject to a large number of stimuli, which strengthens the short-term memory system and diffuses attention;
– compared to earlier times, there is far less need for children to exercise restraint (washing machines can make anything clean again, plastic tools do not break as easily, lost objects can be replaced, etc.);
– there are more holistic and visual stimuli and fewer situations requiring sophisticated and verbal processing;
– due to less movement, less activity is necessary to access information and experience, resulting in fewer precision-based, manual activities and sensory-motor experiences.

When compared to the requirements for school readiness, this list reveals, point by point, how environmental effects impede maturation via reduced reinforcement of the executive functions.

Small children have the brains of hunter-gatherer nomads and are optimised for movement and exploration. The different forms of atypical development that can be identified as delayed or deviant maturation are in fact deficiencies and disorders in the process of the neurological system that turns children into the 'farmer' type. In the case of small children, the neurological functions that are newer from an evolutionary point of view and established the foundations for literacy for humanity embody school-readiness. These functions mean that the child displays the following characteristics:

– has developed a toleration of monotony, is able to sit still;
– is able to focus their attention and maintain it for at least 15 minutes;
– is able to remember sequential pieces of information;
– is able to control impulses and wait with patience;
– their perception is refined and can identify details and relations;
– their movements are coordinated, are able to maintain rhythm.

All of these elements are necessary for both methodical work and the acquisition of school skills. When these abilities are not available to an individual, disorders will arise.

Although the nomadic, hunter-gatherer brain functions may once more be an advantage, the methodical, agrarian, literacy-based activities that have developed the human brain remain indispensable. This is not only true in the case of school: methodical and analytical information processing is also essential for higher-level, synthesising, critical modes of thinking. For this very reason, we need to reinforce the cognitive processes efficient in twenty-first century culture while simultaneously maintaining extant innovations in the human neurological system. A way to assist this process is to begin regarding neurologically-based

performance disorders, which have become more frequent over the past decades, not simply as a developmental disorder in children, but as a signal and guiding light for the directions to take in education and development.

Summary and conclusion

While not always apparent, atypical forms of neurological functioning often lead to atypical development (i.e., learning, attention, hyperactivity and autism spectrum disorders) and are becoming more and more frequent. These atypical forms are not an illness and cannot be cured because they are characteristics of and exceptionalities in the maturation and functioning of the neurological system. These divergences used to contain numerous advantages and may still do so in the future.

Human activity – and changes in it – significantly affect the development of the human nervous system. That is, if the environment changes or is changed, this shift leads to an alteration in the neurological system on the level of both the individual and humanity itself. This change is what happened in the transition from the nomadic lifestyle to agriculture. Founded upon this new lifestyle, literacy subsequently began to spread. In contrast, the twenty first century has seen an unprecedented rate of transition in environmental and human culture, a state that can be best detected in children's development. In children, neurological functioning will adapt to the environment. Atypical development is not a disorder: it is a signal. Its increasing prevalence indicates a slower or different-from-normal development of the neurological functions that prepare an individual for literacy, at the root of which cultural and physical-biological adaptations can be identified.

The culture of info-communication has created a world remarkably close to that of the hunter-gatherer lifestyle. In a growing number of children, we can expect literacy-related maturation to be atypical because developing brains receive less environmental reinforcement associated with the culture of literacy. Beyond cultural factors, other environmental effects influencing the maturation of the nervous system additionally play a role in the occurrence of atypical development. Radiation or chemicals can most readily affect the newer, less basic functions of a developing nervous system. Even though this influence may often not be apparent, it will significantly alter children's development. The neurological maturation that prepares an individual for agriculture- and literacy-related activities, that is, the development of executive functions, is particularly vulnerable to this kind of change given that these functions are more recent from an evolutionary perspective and are consequently less stable.

A deviation in neurological functions can result in under- and over-functioning alike, a phenomenon that occurs in an atypically developing brain. Although each entails opposing kinds of cognitive functioning, this is why both the autism spectrum and the learning disorder spectrum are in fact potentially co-occurring forms of atypical development. In some cases, unstable functioning entails that under-functioning may appear alongside over-functioning.

Atypical development-causing disorders that are not directly apparent are quite easy to influence due to the lack of any serious, underlying injury or developmental anomaly. At the same time, all types of atypical development can take a more severe form (Gyarmathy, 2012). In itself, a change in culture would not lead to so many disorders if we were able to create a learning environment suited to the kind of neurological development that typifies these new circumstances. In order to achieve this task, however, we must first revise our views regarding 'normality' and 'typical development'.

Like the first farmers who were capable of methodical work and controlling their impulses, atypically developing children are indicators of a change in humanity. As humanity faces new challenges, new kinds of activities will prove advantageous. The winner will emerge as a kind of neurological harmony that combines all the functions acquired during the history of the development of the human nervous system. All key elements in children's development, the parental home, school, and info-communication technology must work in concert to attain this goal successfully.

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