

Bridging Neuropsychology and Education

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Abstract

This chapter is divided in three parts. In the first chapter, it is made an attempt to clarify and analyze the relationships between brain's development and learning by examining notions that facilitate this relation such as the notion of function, of functional systems and of instrumental functions. Take for granted the fact that learning boosts brain organization, the second part examines the variables that play a crucial role and have an influence not only on learning but on cerebral development, too. The third part offers an experimental exercise regarding writing. Signature appears as a simple procedure and can be used as a great predictor of prewriting development. It is greatly contingent on age and (pre)school experience and can be used as a vital tool for evaluating learning disabled children who face writing difficulties.

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Part I. Learning neurosciences

1. Learning and brain plasticity

Brain plasticity is a discovery that sheds light on the balance between functional gains and losses along the life cycle. In order to specialize during development neurons are selected for life and death. Neural networks can then be built between the most specialized of them. Indeed there wouldn't be any profit of connecting the biggest collection of neurons. More gains than losses characterizes early development whereas the reverse occurs in adulthood and age-related decreasing learning (Baltes, 1997).

Structural plasticity refers to neuron population, glial cells and growth medium, new axonal growth, new dendritic budding, and new synapses. Nervous system' structural plasticity has been evidenced in adult animals by Raisman, 1969, who demonstrated that new synaptic connexions are formed after experimental lesion in the rat's hippocampus. This researcher succeeded in restoring breathing and climbing by cell transplantation after high spinal cord lesions (Li, Decherchi & Raisman, 2003).

Functional cerebral plasticity refers to two mechanisms in the child: on one hand, the regions that are not yet specialized trigger the process of specialization for the lost functions; on the other hand, the regions that are already specialized revise their specialization.

Wigan, 1844, was the first neurologue to think that one cerebral hemisphere is enough to develop all human cognitive capabilities. In his recent book, Battro, 2000, describes Nino's development, a clever boy with only half a brain. Normal children show large individual differences in pace and rate of development. Plasticity is an expression that has been used to account for variance in the appearance of human skills. On the other hand, Hunt, 1961, suggested that different rearing conditions have differential consequences. White & Held, 1966, have compared early visual-motor development between groups of infants submitted to various enrichment conditions. They conclude from positive results that certain aspects of early development are remarkably plastic. Although generalization of effects and lasting consequences remain open questions, there is no doubt that the infant's brain not only needs sensory stimulation to just live and develop, but is functionally organized by it. The various discoveries in the field of functional brain plasticity change the mind of whoever would think that

the central nervous system is mere a press-button machine with genetical-ly determined wiring. All the discoveries about cerebral plasticity, either structural or functional, have questioned sciences from neurobiology to education and have linked them to form the learning neurosciences.

2. Acquiring and preserving school learning

Research on plasticity explains why neuropsychology became interested in learning. Founded by neurologists who bet on the location of brain lesions only from their clinical observation, neuropsychology wouldn't have appeared without the question of functional loss consecutive to localized brain damage. What early neuropsychologists were looking at, was the disappearance and the contrasting preservation of educational products in adults. Pronouncing language, understanding language, reading, writing and calculating were the targets of their observation. We can say that observation of academic skills after cerebral lesion was the door to understand brain organization.

We could argue that neuropsychology ought to deal first with the highest human values like morality, altruism, love and hate, or the acquisition and loss of religious faith. But this was not the case. Instead, it dealt with every day tools of practical life, communicating and maintaining social independence.

Isn't that also school's first goal to develop all the means of communication, of gaining autonomy by harmonious social life as well as know-how and knowledge learning? Moreover, school assumes the right to evaluate language, reading, writing and calculating in order to orient and select students. The acquisition of the highest human values is preferably delegated to parental education, although school cannot ignore familial education and tradition. We can thus say that reduction of interest in human values to tool use and practical know-how both characterizes traditional school education and early days neuropsychology.

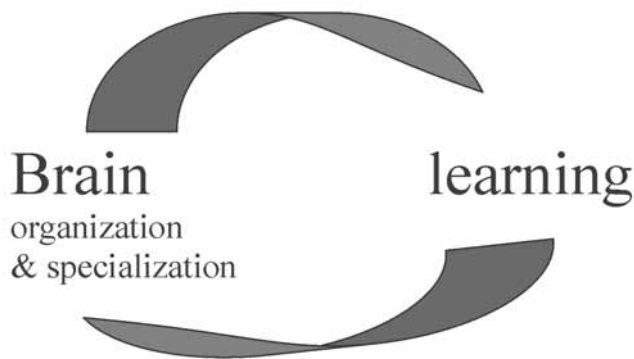
3. The foundation of developmental neuropsychology

It is therefore not surprising that neuropsychology rapidly evolved towards the study of skill acquisition and development. Three main ways of research emerged:

- 1.- fundamental research on the biological conditions for normal development and on the variations dues to cultural influence.
- 2.- applied research on children suffering from brain lesions and on the rules of recovery and intelligence preservation.
- 3.- applied research on learning processes and in children confronted with learning disabilities.

Observations in these fields often looked contradictory: why is there that we can observe an intellectually normal or subnormal adolescent who has grown up with only half a brain? Why is there that some intelligent children with apparently intact brains cannot learn specific school tools, whereas they evidence their normal intelligence in non-school matters? If plasticity explains overcoming functional loss after brain damage, why doesn't apply to dyslexia, for example? These questions represent the core of developmental neuropsychology.

As shown in Fig.1, we consider learning as a powerful brain organizer for permanent learning specialization.



Child Neuropsychology: a question of subsequent specialization

Figure 1. *The brain-learning loop.*

4. Instrumental learning

In order to bridge neurological with pedagogical knowledge, we have to study some notions that better explain the brain/learning relationships: the notion of function, the notion of functional system, the notion of instrumental function.

5. Function

If you are interested to know what neuropsychology brings to education, you have to assume the following credo: no human action or thought, even dreams, is independent from brain functioning. In medical terms, a function is the whole of acts accomplished by a definite organic structure aiming at a determinate effect. This encompasses all activity from cell to organ or even group of organs or system. Neuropsychology studies the functions of the brain as the most complex body organ, and their consequences for the behaviour. As a body organ, brain develops relatively early. Fig. 2 shows the precocity of brain maturation in comparison with other body organs.

The problem is that brain functioning and behaviour are equivocally related during development. Indeed, different brain structures can produce an apparently similar behaviour. At the motor level, Bernstein has demonstrated that a specific movement, like reaching an object, can be attained by several strategies of motor coordination. For example, immobilizing the elbow does not prevent from reaching the target. At a higher level, reading by phonological assembling produces apparently similar results as global reading. In this latter case, neuropsychology had to create a special procedure in order to disambiguate the strategies : the reading of non-words and the reading of irregular words.

On the other side, a specific brain structure can accomplish several functions depending on the contribution of other brain structures or of the variation of external constraints. Cosmonauts have to relearn moving in non-gravitational space, and this shows that the learned motor behaviour has different outcomes with and without gravity. Thus, the function in neurological terms has to be considered as a circular rather than a linear activity, the afferent systems informing the encephalon about how to cali-

brate acts. From the neuronal centre for muscular triggering to the movement realized in space, there is an interplay of regulators, monitors and filters in order to warranty action adequacy.

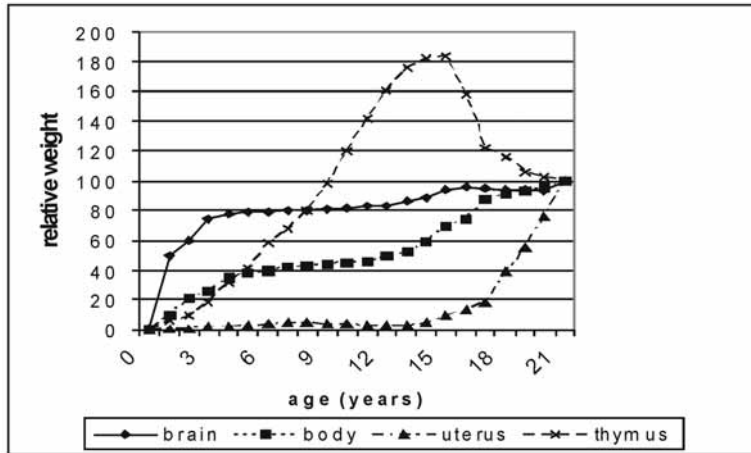


Figure 2. *Precocity of brain development. Comparison with some other organs. (after Braun, 2000, citing Tanner)*

Also the transmission of information between cortical and subcortical systems has to be effective. In psychological processes, like emotional or intellectual responses, most of the messages created in the primary cortex area are mediated and filtered by the forebrain, the limbic system and the basal ganglia before they reach expression. This supervisory system helps keeping a thought for oneself instead of disclosing one's intention, for example.

The contrary sometimes occur: the mediating systems blurr or thwarts expression. The neuropsychology of supervisory systems (Shallice) or of emotional filters interfering with perception and action has attracted much scientific interest during the last decade. Research in these fields also includes concerns regarding education. The supervisory system regulates attention and impulsivity whereas the monitoring of emotions deals with emotional intelligence and the supposed benefit of training self- and other's-consciousness. Here, one can already see the convergence of interest from both neurology and education.

6. Functional systems

This term has been introduced by Luria, 1973, who borrowed it from Anokhin. When the function is no longer related to the activity of a specific organ but is rather defined by the goal and by intervention and collaboration of several organs, Luria proposed the term “functional systems”. The basic feature of a functional system is *the presence of a constant (invariant) task, performed by variable mechanisms, bringing the process to a constant (invariant) result* (Luria, 1973, page 28). A functional system is always complex compared to an organ’s function. It includes interplay and balance between the functions of different organs. It relies on the dynamics of the afference – efference loops. For example, locomotion cannot be achieved only by efferent motor impulses. Therefore it is a functional system.

Luria was willing to explain a hierarchical organization of the brain that can to some extent resume brain development and instrumental acquisition. Let us rely to his neurodevelopmental theory to further explain the relationships between neuropsychology and education. Luria distinguishes three principal functional units to describe the relationships between brain progressive organization and mental development.

The first unit activates the reticular formation whose function is to assure generalized arousal and attention. Beside internal cell life, brain feeds on information provided by the many sense organs. The first cerebral treatment of information is sensation. It refers to the rough shape of the message, aimed at alerting the brain that something new has happened and at attracting psychic attention to the event.

Educators should not confound attention in neurological terms (which often means alertness) and attention in education (which refers to complex involvement in the learning task). Today, we cannot rely to Luria’s theory to explain and treat the kind of disorders we observe when schoolchildren cannot work hard and cannot resist distraction. The problem these children encounter relies more to a general supervisory dysfunction than to any specific pathology.

In comparison with the non-specific nerve set of the first unit, *the second unit* represents specific processing modes of external information. Shurtleff, Abbott, Townes & Berninger, 1993, following Luria’s theory of neurodevelopment, have distinguished three stages in the second unit:

- 1.- The first stage occupies approximately the two first years of development and corresponds to progress in each separate perceptual system, due to maturation of the primary cortical projection areas. The

frontal precentral region (1 in Fig.3), the primary projection cortex for movement, is directly implicated in somatosensory experience (2) since head/body posture and movement change sensory experience. Occipital lobes specialize in visual (3), temporal lobes in auditory experience (4). During this stage, objects are precisely materialized : heat, cold, contact with the body, firm ground, reachable or moving objects, distance, orientation (auditory and visual). The perception can be declined: it is neat, long, red, it has a black point at one end, in brief a clearly recognizable object.

- 2.- The second stage approximately corresponds to age 3 and 4. Functionally, this is the stage for perceptual-motor integration as well as progress in perception, for example in acquiring the sense of external space from visual, auditory or proprioceptive experience. Maturation of the secondary projection areas of the brain, or association areas, permits synthesis of the separate sensory perceptions.

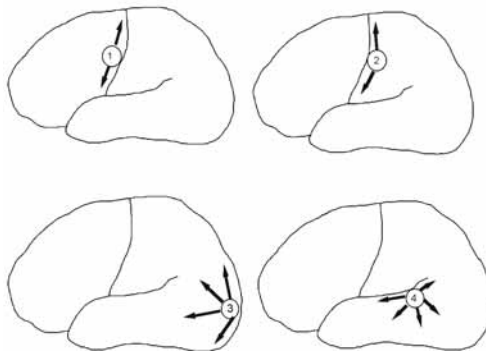


Figure 3. Gradients for the emerging of functional networks. (after Rosenzweig & Leiman, 1991)

- 3.- The third stage starts at 4 or 5 years of age, when the proceeding mental activities achieve multimodal integration and realize preoperational thought through language, gnosis and praxia. These are symbolic schemes applied to one's own action as well as to the physical and the social world, i.e. to the other's thought. When the child recognizes the clearly recognizable object as a "pencil", he/she achieves a « gnostic » performance. He/she can mime the use of the pencil in order to show the examiner that there is no uncertainty about the object. The pencil also becomes a specimen of its category, i.e. graphic tools.

Gnosis reach the denotative stage of perception: you can provide other

samples of the same object or finds synonyms. There is no longer any doubt about the conventional use and naming of the object. Note that the use of many objects is culturally influenced and that the brain reaches, with gnosia, a stage of cultural differentiation, a stage of symbolic learning.

If we now consider movements, the same differentiation sees motility progressively transformed into praxia, object use ability and symbolic pantomime. Abstraction permits the child to mimic sadness. Writing or playing music are the most advanced acquisition of manual movements whereas the whole body expresses itself in dance and sport, for example.

Language follows the same track of differentiation during development and brain organization. Language becomes in the service of imagination and creativity.

We can draw parallels between the three progressions: from afference to gnosia, from motility to praxia, from auditory attention to language. All these abilities take several years to be learned and can be improved by further learning and training during life.

Neuropsychological examination in a learning disabled child basically concerns language as well as gnosic – praxic abilities and the relationships between them.

Table 1 illustrates the theory of hierarchical functional systems and put forth the relationships between the different learning neurosciences. Note the common denominator of the different developmental sciences which is learning.

Related sciences					
functional systems	physiology paedagogy	neurology	neuropsychology denotative	psychology connotative	
sensory, tactile & visual	afference	sensation	gnosia perception	visual thinking	learning maths
motor	afference	motility	praxia movement	practical intelligence	learning graphia
auditory	afference	sensation	phasia perception	verbal thinking	correlating written tooral language
-----learning-----					

Table 1. *The learning neurosciences.*

This table shows how the related sciences eventually study the same functions but at different stage of their chronological appearance during development and of their hierarchical level when activated. It shows that education contributes to neurosciences by bringing mental tools inherited from physiological, neurological and psychological development to further steps of efficiency through learning.

With maturation of Luria's second unit, information processing becomes more connotative and can even be purely symbolic. In language, for example, words and concepts are bypassing perceptual reality and concerning relationships between objects as much as real objects themselves.

Learning maths becomes a functional system on its own which nevertheless cannot develop without basic tactile and visual representation of quantities and positions.

Table 1 artificially represents verbal and practical intelligence as separate functional systems. Even if these two intelligence forms are evaluated separately in every day psychological practice, we know that many practical tasks are accomplished with linguistic support and that many linguistic tasks can be resolved by visual representation.

So there are more developed functional systems to intervene, i.e. systems of collaboration between the functional systems described so far.

Luria's *third unit* serves at programming, regulating and controlling activity.

This is the role of supervisory functional systems. Third unit functions are called executive and have been particularly well described by Luria studying the role of the frontal lobes of the brain. Actually executive functions are mediated by the prefrontal areas, a tertiary cortical zone that is related to all other cortical regions as well as to the afferent/efferent structures of the thalamus and of the basal ganglia (see chapter from Karapetsas).

If you add the supervisory cognitive system to the functional systems described in table 1, you will obtain an image of a brain which links together neuronal functions belonging to distant cerebral structures.

Thinking no longer of functions and functional systems for themselves, but rather of collaboration between several functional systems, one inevitably sheds light on the temporal organization of the brain in any activity. Intelligence is also a matter connection velocity and of brain flexibility observed from a real time paradigm. Here, we almost reach a virtual brain that never shows itself working outside a defined time.

For example, if you ask children to be as kind as to suffer a functional brain imagery examination while realizing a precise calculation task in order to watch directly the brain working, you have to choose the machine which gives the best account of activity in real time. If you chose a machine with low time resolution, you will get an image of the brain working as a whole. You can also obtain images of specific strategies used by the children depending on the record's window of time. In this case, you are facing the problem that two children provide different images.

7. Instrumental functions

By this term we more precisely refer to complex every day activities accomplished at home, school or work. They are characterized by long-term acquired experience. Only a few subcomponents, like motility or perception, are innate. Instrumental functions appear late in life. They are mostly adaptive in that they meet environmental (familial, academic, professional) strong requirements. Moreover there are favorable, if not « critical », periods during which these functions can be learned.

Instrumental functions only appear after a period when language, perceptual processes and psychomotor abilities have attained an optimal stage of differentiation and coordination. This maturity stage corresponds to school-readiness, reading-readiness, writing-readiness and calculating-readiness. The child only reaches this stage after approximately five years of preparation. Before that, only simulation could mimic these activities, like for example speaking about numbers, pseudo-letter writing, pretending to read and improvising from form recognition.

Notice this five-years period during which no parent, no teacher, no physician, no child him/herself can be assured that he/she will become functionally literate, even if 95% of the children in the general population reach this stage (if we count only 5% of strict learning disabled, it is, raised in favourable conditions for learning) .

8. Instrumental learning and learning disability

Typically, the learning disabled child enters a phase where he/she will disappoint his/her parents. This is new for him/her. Parents get angry, do not understand the reason why this well-grown and obedient boy/girl ceases to reward them with success. The cause of the failure is very often attributed to the school and to some particular person within the school. Dynamic psychology often makes a mistake about this failure and points to the new parent-child relationships since the child recently passed through the oedipian phase. The child is depressed by not rewarding his/her parents anymore, namely with formal reading, writing and calculating success. Comparing him/herself with classmates, the unfortunate schoolboy/girl often panics and becomes depressed or even rebellious.

Much diplomacy is needed to inform school and parents about the vicious circle that brings both of them to accuse each other. We think that this parent-teacher misunderstanding about a child who shows a mixture of school failure and behavioural difficulties often leads to disruption with the school, worsening the feeling of social failure or exclusion.

Since Hinshelwood's hypothesis (1895), and since Morgan (1896) and Kerr (1897) first publications on pure dyslexia in children (called at that time «word blindness»), a century of studies in the field did not make schools more understanding and welcoming towards these children.

In countries where non-state schools exist, this process literally nourishes private establishments and institutions. Actually, the psychological reactions to specific learning disabilities we are describing alleviate the charge of the Education Department, reinforcing the illusion that its responsibility, contrary to modern laws and charts, only concerns those pupils who learn well.

We think that not enough was taught in the universities about functional and instrumental disabilities. The temptation strongly remains to hallucinate about a specific genetic disorder or a specific and invisible brain lesion. This trend precisely illustrates the confusion between dysfunction, i.e. organic dysfunction, and instrumental dysfunctioning. It is well possible that a genetic abnormality leads to specific brain organization which in turn hinders fluidity of information within the brain. Some flexibility between the different strategies of efficacy may be missing. Many years of brain specialization and of learning from environment separates early expression of a genetic disorder and late appearance of academic disability. The relationships between a genetic abnormality and a cognitive consequence that only appears five years later looks very indirect, although theoretically not impossible.

Mixed cases of real brain damage with developmental difficulties make us think that all learning disabilities are of structural neurological origin. This is specially the case with premature children or children born at risk with low birth weight, when the brain has to suffer a clear insult. But most of the learning disabilities probably are purely functional, as far as we know from nowadays modes of examination. Some authors have suggested that it would be better to have only half a brain than to suffer from a functional generalized damage, like it is the case with prolonged hypoxemia. Brain plasticity can only occur with large sane neuronal tissue. We should therefore not consider a functional damage as less severe for mental development than a structural lesion.

Permanent learning disabilities contradict the law of recovery by plasticity. Much remains to be discovered to understand why the disabilities reveal themselves late in life when no early dysfunction can be evidenced. We can only bring up the neurodevelopmental model to stress the possibility that early mild brain insult can have severe and late appearing consequences on mental functioning and learning.

Part II. Rules for development

Keeping in mind that learning disorders and organic brain damage can produce similar habits, let us cite very general rules governing neuropsychological development.

The first rule is that early learning mobilizes the brain as a whole. Modularity within the infant's brain is not functional, even if each hemisphere and each particular brain lobe or area already has the information for its further differentiation. This means that the fetus' and infant's brain needs to be fully intact in order to preserve all the potentialities for its subsequent specialization. This is Dennis & Barnes' counter-proposal to plasticity.

The second rule concerns the right time for each learning to take place. Whenever some particular learning cannot be done at a specific moment of brain maturation and specialization, abnormal competition between the different acquisition processes arises. In this case, harmonious blending and integration of learning as a whole is hard to achieve. Postponement of a specific learning actually changes learning quality and its relationships with previous and simultaneous experience.

The third rule refers to the necessary pace for each learning. For example, if a certain children say Peter needs two years in order to achieve a certain task, whereas his age peers need only one, one might ask oneself what the other children have learned during the second year in comparison with Peter. Theoretically, they have learned new tasks at the same pace and we now know that Peter will most probably not reach comparable performances even if he had one supplementary year to do so. Instrumental learning no longer appears as the acquisition of equivalent bits or units of experience but rather as a hierarchical process which becomes progressively more complicated and integrated with time. This accounts for the tendency of Peter's developmental curve to never catch up his backwardness in learning if specific training is not offered to him early enough in his life.

1. Brain development aims at autonomous adaptation to the environment

Human skills evolve from interactions between the individual and his environment. These skills are of two kinds: those acquired by everyone with a minimum of common experience, for example language, and those depending directly on features of the environment, for example the mother tongue.

Genetically transmitted development programmes exist for these species-specific skills. However, such programmes are subject to selection even before they produce these skills. Specifically, certain development programmes are confirmed by interaction with the environment, thereby stimulating maturation of the corresponding neurological structures. These programmes are able to prioritize development to a certain extent. For example, in a favourable environment, the development of the mother tongue seems essential, not just from the social point of view, but also from the standpoint of cerebral organization. Other programmes, by contrast, are invalidated by the absence of adequate environmental conditions, and this can potentially result in a certain atrophy of the neurological substrates of the programme.

Mental development does not just involve one single programme, but rather a number of programmes corresponding to the various functional and instrumental systems. These programmes follow specific schedules, with differentiation phases, roughly corresponding to defined chronological ages. Certain development programmes remain in a state of abeyance and appear only in the late childhood, or even in late adolescence. These

are internal organization programmes, a precondition of which is specialization of certain functional systems with a view to their coordination. Learning how to read, behavioural control and emotional control are examples of such programmes.

Selection assumes that the acquisition of these skills is ultimately the positive outcome of a balance sheet of gains and losses, as we have already mentioned. The expected development of a normal child corresponds to a relative maximizing of gains and a relative minimizing of losses. This process is dynamic over time and validates the idea of a "mental development potential" for each child. This potential can at best be evaluated by longitudinal observation.

However, child neuropsychology faces the challenge of evaluating the potential for mental development through functional processes that are not yet specialized, but the aim of which is to keep certain cerebral regions in a state of perfect health with a view to subsequent specialization.

Even at birth the human infant is already equipped with the potential for mental development, but at no point in the individual's lifespan can one state that the architecture of the psyche is complete, as Baltes, 1997, puts it. So, even for the normal individual, neuropsychology concurs with the idea of the philosopher Tetens, expressed in 1777, that human development is essentially incomplete (*ibid.* p. 366).

In the case of brain damage concerning a child, the dynamics of gains and losses is much more difficult to determine than in the case of a healthy child. Specifically, this is because the processes of growth are accompanied by those of structural and functional cerebral plasticity (table 2).

These two types of plasticity, structural and functional, seem to provide the child with a special potential not only for mental development but also for recovery. However, recovery by plasticity involves a change in the genomic programme and, compared to normal development, an added risk for the prospective specialization process, where incompleteness, competition and overload, and finally lack of coordination can occur. We assume that a developmental deficit of this type lies at the root of most of the learning difficulties in which a specific instrumental dysfunction is diagnosed. Prenatal distress, in particular, often leaves no observable trace on images of the brain several years later. Insofar as they are circumscribed, and provided a sufficiently large cerebral mass is spared, growth and plasticity are sufficient, initially at least, for ensuring the development of all the basic functions. However, the prognosis for their coordination at a later stage of development is still restricted. In fact the existence of true dyslexia, for exam-

ple, is living proof that recovery by means of maturational growth and plasticity has its limits. We would like to stress the point that incompleteness of recovery in the case of children with cerebral lesions is mere an added condition to the essential incompleteness of the human mental architecture.

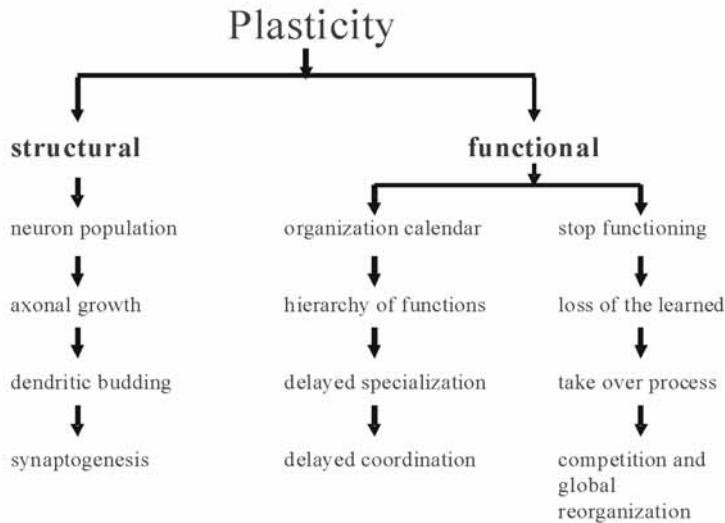


Table 2. Definitions of brain plasticity.

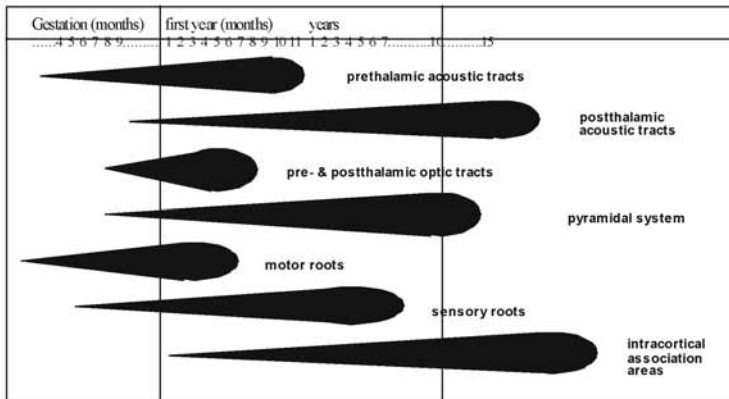


Figure 4. Myelination as representing functional development. (after Yakovlev & Lecours (1967), simplified by Habib (1993), and after Lou (1982) redrawn by Michel & Moore (1995).

2. Timetables for functional organization

The functional organization and the maintenance of reorganization capability depend on ongoing processes which influence the way brain areas carry on with their own schedules of development and interconnectivity, and these processes define brain functional development during the whole of childhood and adolescence.

This relates firstly to myelination, which we know, from the work of Yakovlev and Lecours, to be differently timed, depending no longer on necessity for cell life but on needs for the life of the organism. Learning becomes the psychological expression of this vital spirit. From now on, we can follow the growth of different functional systems (fig.4).

The first transition between reflex and voluntary behavior relates to sucking and gaze. Then optic tracks and visual systems mature during the first postnatal months. Acoustic tracks become functional in two separate steps: firstly prethalamic maturation insures auditory receptivity, secondly post-thalamic circuits contribute to the development of auditory sensitive discrimination which permits verbal differentiation necessary to specify the mother tongue.

Meanwhile, voluntary movements have been available to insure fine prehension and the various modes of locomotion.

Note the last myelinating circuit, which renders interconnecting structures functional, among which are the associative parietal cortices, the interlobic tracts, namely the angular gyrus, the corpus callosum, and the prefrontal cortex.

Yacolvev and Lecours' diagram permits the impact early brain damage can have on cognitive development to be theoretically evaluated. Let us consider what would happen if the child suffers a brain insult at birth or during the first year of life. Priority in maturation would be assigned to recovery of the developing functions. Verbal differentiation and association of verbal with non-verbal functions will not be involved in the recovery process. The recovery of the early vital functions will be given priority until all the first-year abilities become fully developed. The development of the associative areas could be suspended without any observable sign of what might become a late deleterious effect of early brain damage.

Johnson, 1997, compares synapse formation, as presented by Huttenlocher and de Courten (1987), with consumption of glucose within the occipital cortices, as presented by Chugani et al., 1987 (figure 5). This illustrates brain functioning during child development, peaking around the crit-

ical 4-7-year period, which no longer corresponds to maturation either of motor or of sensory systems, but reflects the mobilization of associative cortices during the first few years of school. Johnson concludes that brain maturation in humans proceeds at least into the second decade of life.

From the physiological point of view, the peak at this age corresponds to the greatest increase in intrahemispheric coherence, as measured by EEG interregional correlations (Thatcher, 1992). From the cognitive point of view, this peak represents the major increase in short-term and working memory, as reflected by results in the auditory span test (figure 6).

Interhemispheric connectivity can be measured by what is referred to as the bilateral field advantage, the fact that symmetrical targets presented bilaterally and simultaneously are perceived better than non-symmetrical targets. This advantage reveals the progressive functional availability of the interconnections of the left and right hemispheres, a process typically corresponding to late maturing functional systems.

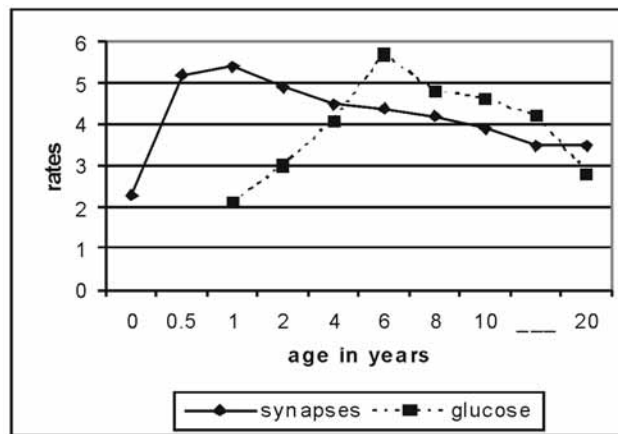


Figure 5. Brain functioning: production of synapses /mm³ compared to glucose consumption. (after Johnson, 1997)

Thus there is evidence that although the major step in brain growth takes place within the first two or three years of life, a certain potential is held in reserve for subsequent functional specialization. It should be noted that the maturation of this tertiary functional system (or *third unit*), according to Luria, corresponds to the emergence of subtle advantages in cognitive functioning that at best can be observed experimentally. The

mental processes concerned probably demand the maximum of internal thought, they are internal processes which have become relatively independent of direct perception and mnemonic procedures.

Remember that the last stage in Piaget's cognitive model of development precisely relates to "formal" thinking, processes relatively free from spatial and temporal constraints. We know that Piaget and Luria met and discussed development. For us, there is no doubt that Luria's model of tertiary development of functional systems encouraged Piaget to specify the kind of cognitive ability to which these functions are subservient.

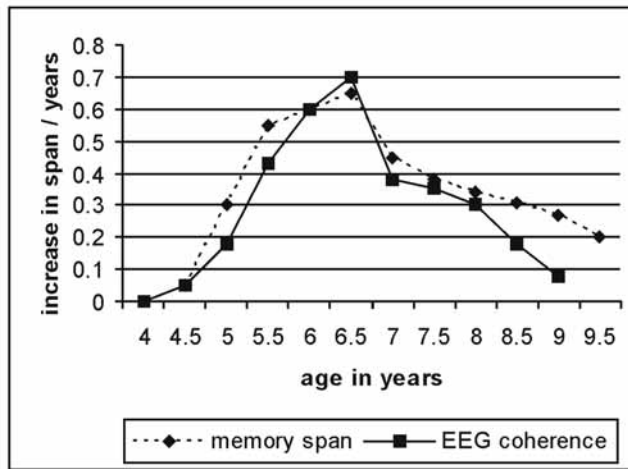


Figure 6. Memory capacity and EEG brain coherence. Rate of growth of working memory (digit and spatial span) (after Johnson, 1997) compared to rate of growth in EEG coherence between frontal and posterior lobes during middle childhood (after Thatcher, 1992, see Johnson, 1997).

3. Erratic developmental trajectories

The idea of linear and regular mental development has been inferred from the monotonous accumulation of knowledge, in much the same way as years of age accumulate. The normal curve of development indeed holds some attraction, for instance it represents the best conditions for development. Pre-term infants, for example, show growth in height re-

sembling the curve exhibited by at-term infants during the first year of life (Wooley & Valdecanas, 1960). Contrary to a progressive lag in weight growth, pre-term infants do show the same slope of development as at-term infants, i.e. the same growth rate throughout the period considered. Therefore, the normal rate of growth serves as nothing other than an expectation, and represents the potential for further progression. Indeed any discontinuation in the progression would necessitate an extra propulsion mechanism if recovery is to be expected, corresponding to a catching-up slope. If not impossible, this propulsion mechanism is very rarely observed.

We should ask ourselves whether the normal curve of development is valid for all growing abilities in the child. Alternatively, monotonous development is merely an illusion, which conceals gains and losses in many areas of mental functioning. What we consider as learning in fact results from the appearance of ones particular ability, carefully timed, and sometimes from the disappearance of others. Let us consider the development of verbal behavior and cooperative play.

Verbal behavior emerges as a predominant type of behavior at a time when emotional and motor behavior regress. Although we are bound to the categories of observed behavior, the timing of this behavioral change is striking and corresponds to the age of 30 months (fig.7).

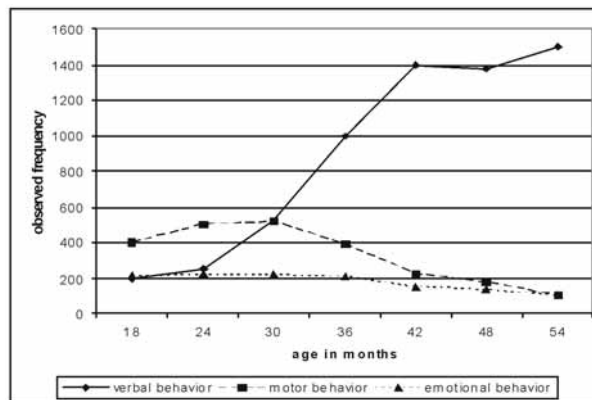


Figure 7. Language acquisition correlates with inhibition of both motor and emotional behavior. (Data from Ames, Ilg & Haber, 1983, after Deldine & Vermeulen, 1997, see Braun, 2000)

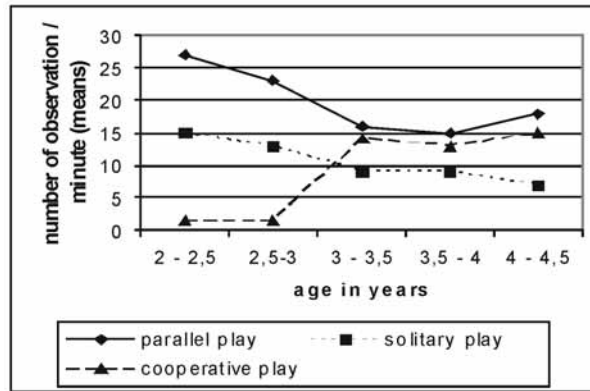


Figure 8. Development of three different play styles. (Data from Parten, 1932, after Shell & Hall, see Braun, 2000)

If we consider the type of play (fig.8), we observe that cooperative play, either as parallel synchrony or intensive partnership, progressively replaces solitary play. The decreasing behavior does not disappear and does not correspond to abnormal behavior. The last example is concerned with the decline in a specific ability after its rise during the primary school years. Neopietagians are fascinated by the fall in a previously rising ability, because the fall precisely contradicts a continuous and successful reorganization of behavior.

In Pelizzer & Hauert's example, the ability consists in pointing to a target with either hand, in either the ipsilateral or contralateral visual field. Only from 8 years of age on is a left-hand superiority over the right to be observed in right-handed children, in either visual field. Here we observe a non-dominant hand advantage appearing quite late in the child's development. However, the suddenly acquired advantage vanishes two years later, as does the overall ballistic precision (fig.9).

In our mind, these irregularities within the cognitive as well as in perceptive-motor development bring into question the meaning of the normal developmental curve.

Normal curves of development are continuous and regular; this observation derives from statistical inferences, not from observation of the development of a single case.

We think that in just the same way as organs, neurons and brain specialization develop in a non-monotonous fashion, physiological functions

and mental abilities develop by combining gains and losses. Mental growth appears to be a continuous adaptive process, which only mimics a cumulative process, but by no means is one.

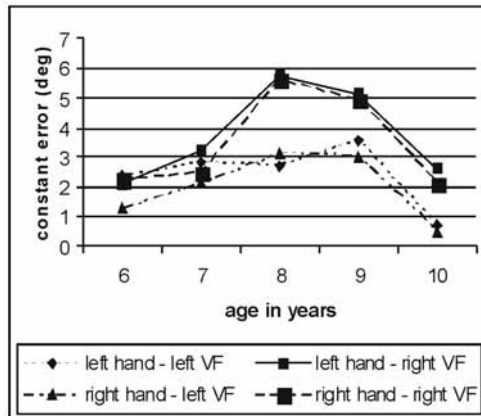


Figure 9. *Spatial accuracy in arm and hand aiming. Constant error by hand, visual field (VF) and age group. (after Pelizzer & Hauert, 1996)*

4. Lateralization studies

Lateralization studies form part of the study of brain specialization. Progressive asymmetry, as well as progressive symmetry, is not to be understood as contradictory observations, but as the progressive contribution and coordination of two specialized hemispheres in an intergraded mind.

5. Learning boosts brain organization

Visual total deprivation does not need to last very long before the visual cortex undergoes restructuring, eliminating the cells previously prepared to acquire visual cue receptiveness. If vision is repaired later on, visual abilities will never develop as if deprivation never occurred.

What effect does experience actually have on cerebral development?

Rosenzweig & Leiman, 1991, consider three main effects of experience on neuronal development:

- a) experience has the power to boost neuronal development throughout the period of dendritic maturation and the proliferation of synapses (fig.10, 1st. line);
- b) experience has the power to accelerate neuronal development, which means a reciprocal effect of brain construction and learning (fig. 10, 2nd line 3);
- c) experience helps maintain neuronal network specialization, therefore always permitting new learning based on previous learning (fig. 10,3d. line).

These sketches illustrate well that, with poor experience, the brain grows more slowly, synapses are established less completely, and that further learning starts from a weaker or even already degraded base. This suggests that although there are critical timetables for developing the different nervous systems, experience actually represents one of the major growth factors, particularly characterized by long-lasting effects embedded in a cumulative process.

The same authors empirically confirmed their theory by providing results of early and late adoption in three nutrition condition groups (fig.11, groups 1,2,3).

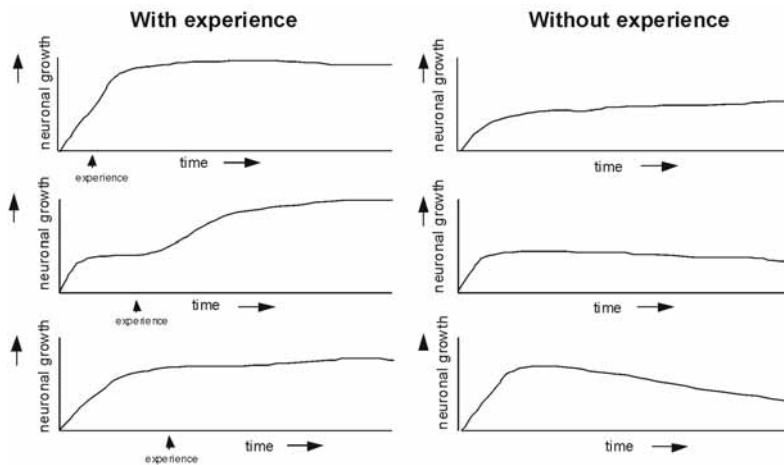


Figure 10. Experience and neuronal development. (after Rosenzweig & Leiman, 1991).

The effect of early adoption in catching up normal heights is striking when compared to results from the late adoption group. However any lasting physical deprivation, such as malnutrition here, hinders the catching-up process. Regarding IQ, we again see better outcomes in the early adoption group, and again all long-term deprivation, even nutritive, slows down the general progression of intelligence.

Observations of severe social deprivation show by the negative that experience boosts brain development throughout the period of childhood. However, to take advantage of experience, brain matter must be intact, and the brain must function in substitute activities throughout the deprivation time.

This is illustrated by Skuse's observation of Mary and Louise, two sisters raised in isolation by a mentally deficient and deaf mother (fig. 12). Louise was born first, and Mary joined her when she was three in the dark and locked room. At the time of the girls' discovery, Louise was 5 years old and Mary 2. Both girls were then raised in warm, therapeutically rich environments. Louise's language progressed rapidly and reached subnormal level during her school years.

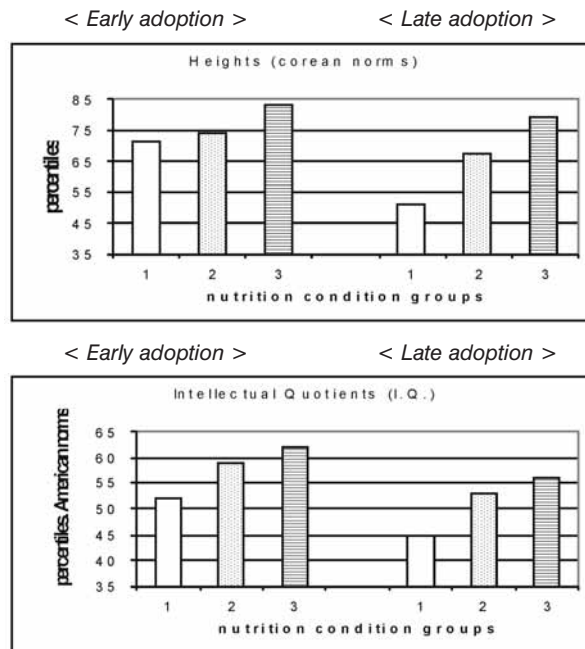


Figure 11. Effects of early and late adoption in three nutrition condition groups. (after Rosenzweig & Leiman, 1991)

Mary never recovered functional language, after a period of simple oralization. Louise was discovered as genetically and neurologically healthy, whereas Mary showed the same microcephalic condition as her mother. Mary and Louise's history of recovery from severe social deprivation illustrates the fact that even after five years of silence, although Louise was not alone from three to five, language recovery was possible, if not to a fully normal, at least to a good functional level.

This observation is not the only one to show language recovery after more than five years of silence (see Mason, 1942), but it shows that, providing intact brain structures have functioned in any struggle for survival, they can specialize later than expected for the species, probably not at no cost, but certainly far beyond what a strict rule of a precocious critical period for language would have predicted (Lenneberg's theory).

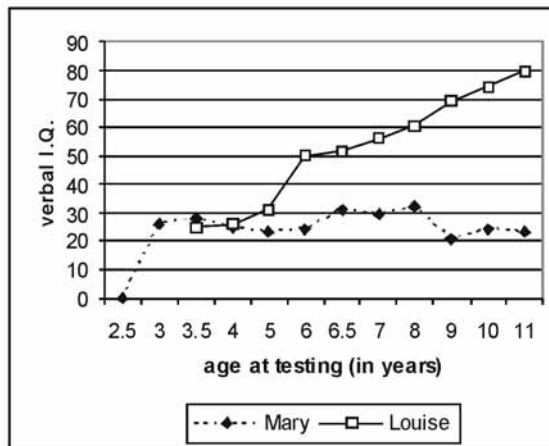


Figure 12. Severe deprivation. Language understanding from the time of the girl's discovery. (after Skuse, 1984)

Why is continuous accumulation of normal acquisitions important for further learning?

Recently, Locke, 1997, provided an important model for explaining learning disabilities, particularly those disabilities that reveal themselves progressively. According to Locke, not only scheduled learning but also a critical amount of learning is necessary for further exploitation of what has been acquired (fig. 13). This example is concerned with language, a cog-

nitive ability characterized by different steps of production and analysis.

In figure 13, we can see the expected consequence of an insufficient stock of resources, so that the three-year-old child with poor verbal acquisition will never develop analysis of language, described as an ability to both think in verbal terms and think about language. Of particular importance is the notion that whether the child develops language analysis or not does not depend on time of learning but on efficiency of learning during the same period.

To summarize, continuous and rich experience appears to be one of the most important factors favoring mental development. This is not really new. But we should keep in mind the conditions under which this experience boosts brain and mental development. Particularly for clinical cases, it should be remembered that the integrity of all the brain structures typically permits the assimilation of experience and the cascade effect of acquisitions. For complex cognitive functions, efficiency has to be attained, within a certain critical period, so that more complex functions, corresponding to the next step of normal acquisition, finally emerge from within, from a reserve of sufficient resources.

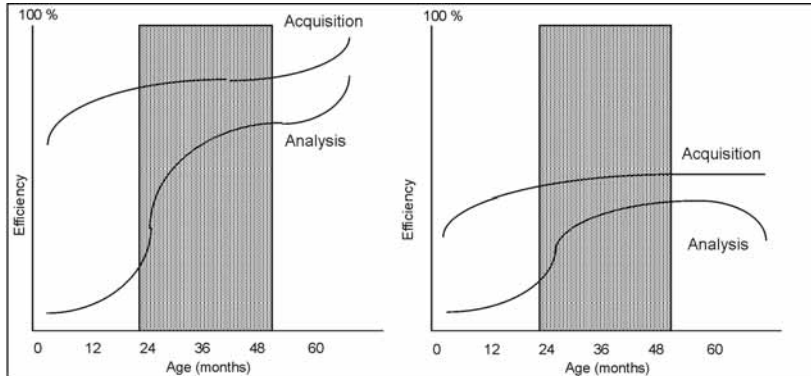


Figure 13. Schedule of developmental linguistic mechanisms. Rich lexical acquisition promotes utterance analysis. (after Locke, 1997)

6. Brain damage learning disabilities: reflections on developmental trajectories

We should perhaps specify what learning disability (LD) represents in comparison with brain damage. In agreement with several developmental neuropsychologists, we consider learning disability as a developmental disorder which does not, on the basis of present-day technology, reveal clear signs of associated neurological injury. This means that these children have no known history of brain insult and were born with normal neurological ground status. Sometimes, the history of pregnancy and birth lead to suspicion of brain damage, and identify these babies as being at risk. The interesting thing about LD is that it reveals itself progressively in child development as a specific learning disorder. Today, we still do not know why. Because, if there is no gross neurological pathology, brain plasticity should prevent the development of such a disorder. I would like to propose that learning disability is actually brain damage without spontaneous plasticity.

The general rules for understanding outcomes from brain damage in children only emerge from longitudinal observation, where it can be noted that

- 1.- age of the child at the time of injury;
- 2.- extension of the brain damage; and, if focalized,
- 3.- localization of the damage, all three greatly influencing mental recovery. We should add a fourth factor that counts for methodical observation:
- 4.- the time elapsed since injury.

For prenatal and neonatal damage, the chronological age, or compensated age for pre-term infants, directly represents the time elapsed since injury. However, the concept of "time elapsed since injury" not only includes neuropsychological sequel, but also consequences of psychological and social deprivation the child has suffered because of the injury.

In infants, functional equipotentiality between the two cerebral hemispheres for realizing specific behavior or abilities has been considered as an explanation for recovery from early brain damage. The traditional example of functional plasticity refers to the fact that, although almost all adults produce speech with their left brain, there is no effect of lesion laterality on the subsequent development of language capabilities in small children (Lenneberg, 1967).

This is what observation of congenital hemiplegics indicates. However, congenital hemiplegics show a particular fall-off in their verbal performance, for example in vocabulary development, from about six years of age (Banich et al., 1990). This illustrates the delayed disability emerging long after congenital brain injury, irrespective of the hemisphere affected (fig. 14). Another challenge comes from observation of early differences in the consequences of left and right hemispheric lesions in toddlers.

Indeed, Nass & Koch, 1987, already recorded mood differences according to the side of the lesion in very small children (figure 15). Particularly in right brain injury cases, they observed expression of negative mood, disturbance of rhythm, loss of attention and disrupted social interactions. These problems do not differ greatly from those observed in adults suffering from right brain damage. So, the right brain seems to develop faster than the left in the first part of postnatal development (this is well established) and it seems, according to these results, that some of its specialization at least is acquired very precociously.

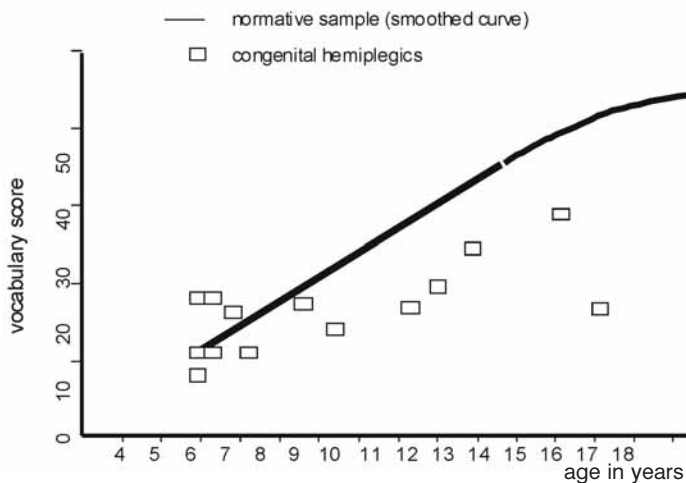


Figure 14. *Congenital hemiplegics. Falloff in vocabulary learning after age 6-8. (after Banich et al., 1990)*

To summarize, from one function to another (and there can be many different functions in language), the rules of hemisphere dependence change, so that plasticity effects are sometimes apparent. This does not

mean that plasticity permits all kinds of recovery at no cost, whether we consider immediate or delayed effects.

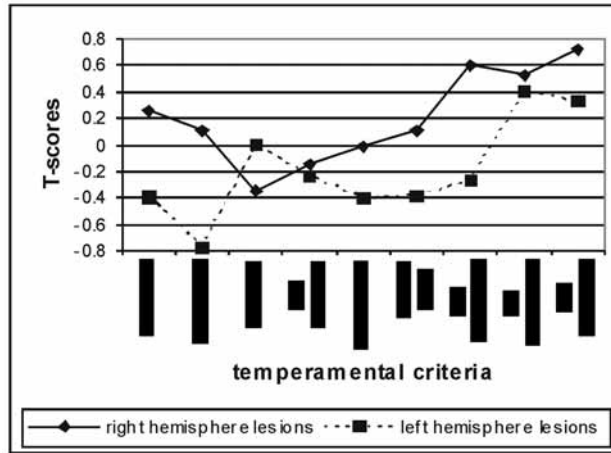


Figure 15. Early temperamental differences in brain-damaged toddlers regarding the side of the lesion (after Nass & Koch, 1987). Right hemisphere lesion's characteristics: high activity, arrhythmic, negative mood, loss of attention, poor interpersonal relations.

7. Do young children recover better from brain damage than older children and than adults?

Montour-Proulx, 2000, provided new data from longitudinal observation of mental development in young and middle age children, compared to adults (see Braun, 2000; see also Duval, Dumont, Braun, & Montour-Proulx, 2002; Montour-Proulx, Braun, Daigneault, Rouleau, Kuehn & Bégin, 2004), all of whom have suffered from an unilateral cortical lesion. The younger age group consists of 39 children with congenital or acquired brain damage during the first year of life. Children of this group are tested from the age of three.

The middle childhood group consists of 43 children with lesions acquired between 1 and 8 years of age. and tested when they reached at least 6 years of age.

The older age group consists of 28 subjects who suffered from brain insult after 9 years of age and were tested from age 12.

The point here was to test Margaret Kennard's suggestion that recovery from precocious brain damage is more effective than recovery from damage sustained later during childhood. To verify Kennard's hypothesis, laterality of lesions was not considered (fig. 16).

From Montour-Proulx doctoral thesis' results, we can observe that congenital lesions or lesions sustained during the first year of life have more deleterious effects on IQ than lesions acquired during middle childhood. In comparison, older subjects and adults show, on the contrary a vulnerability of their visual-spatial performances after brain damage. Verbal abilities are more resistant to cerebral lesions in adults compared to children. This reflects some aspect of neuropsychological maturity in adults.

These results clearly contradict the idea of better recovery in children than in adults.

Now we can ask the question of hemisphere dependence. Montour-Proulx (id) provided results considering the lateralization of the lesion (fig.17). The dependence on the side of the lesion is different in children compared to adults. In children, there is only a slight laterality effect in the direction of that found in adults. As a group, left-hemispheric brain-damaged obtain lower scores on verbal IQ, and the reverse is true, but the differences between verbal and performance IQ are not statistically significant.

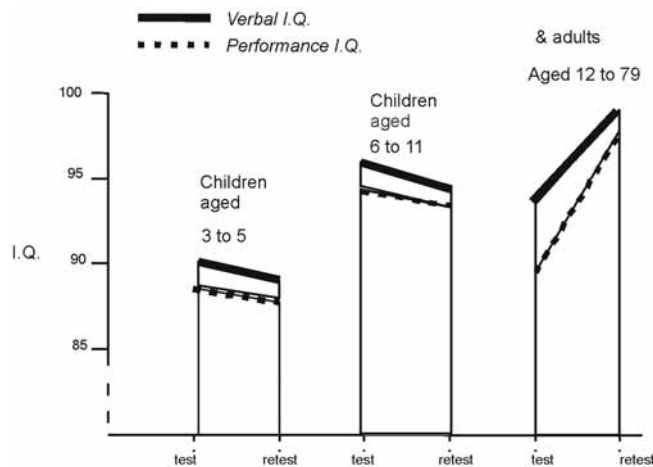


Figure 16. Test of Kennard's hypothesis. I.Q. test-retest (3 yrs interval) depending on age at insult). (after Montour-Proulx, see Braun, 2000)

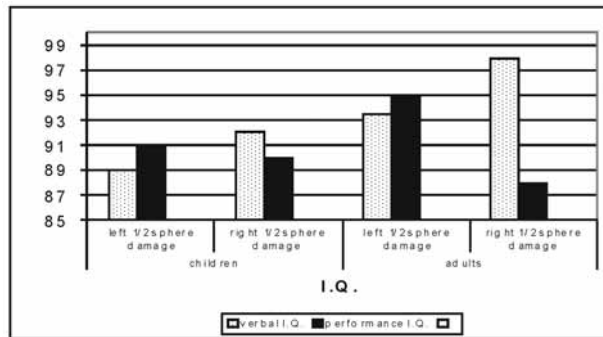


Figure 17. Lesion laterality effect in brain-damaged children and adults. (after Montour-Proulx, see Braun, 2000)

In adults suffering from right-hemisphere lesions, visual-spatial performances are symptomatically declined, whereas verbal IQ are preserved. Left hemisphere lesions in adults have consequences both on performance and on verbal IQ.

To summarize, we have seen that brain damage in childhood has a deleterious effect on longitudinal development, sometimes with late-appearing disabilities. Although there are signs of lateralization effect in brain-damaged children, the recovery in terms of verbal versus non-verbal abilities is independent of the lesioned hemisphere.

Furthermore, the developmental quotients are not the best way to account for consequences of brain damage in children, since IQ decline does not mean that the child progressively loses its abilities. We should differentiate relative and continuous regression in brain-damaged children, the latter being very rare, as can sometimes be observed in symptomatic severe epilepsy.

Three mental growth factors

1) A natural adaptive process

We can sum up the preceding considerations by questioning the representation of neuropsychological development in brain damaged and learning disabled children.

Firstly in normal, individual mental development does not necessarily

appear as linear and regular. However, for every child, there are critical steps in brain and mental organization. Basic instrumental skills, like sensory and motor skills, have to be trained to the point where they give way to mental representation, among which are language and spatial maps. This representation in turn enriches sensory and motor abilities. There is a long-lasting consolidation period, corresponding approximately to the preschool years, where progress in language, body schema and visual constructive abilities represent well-established specialization of those brain areas which are subservient to the "what" and "where" interpretation of reality, as well as sensitivity to time sequencing.

Around the age of 5 or 6, these fundamental symbolic competences enter a phase of combination, for example timing of motor activity with visual perception, or of verbal with iconic symbols. This type of combination is highly dependent on the stabilization of the former and isolated symbolic learning, at least at a certain level of expertise. It also depends on facilitating impulses coming from a sufficiently rich environment. At this level, the "callosal mind", as we have called it, represents bi-hemispheric coordination of specialized skills (see Gaillard & Converso, 1988). One model of learning disability would consist in a competition, instead of coordination, between unspecified brain activities.

From the time the child learns to read and write, previous intuitive skills can disappear, and this decline appears necessary for the child to use multimodal representation of reality. This process provides the child with a choice of cognitive strategies, while trying to solve mysteries of written representation. The brain gains in coherence what it loses in separate expertise.

It has been noted that there is a further step of late nervous coordination, revealed by glucose consumption, which shows a peak at around 7 years of age. Brain coherence, callosal mind, even myelination of association neural networks, increase in glucose consumption, highest performance in working memory, consolidation of the frontal relay between neocortical and subcortical systems: these are typically the secondary and tertiary functional systems that develop during middle childhood.

This abbreviated sketch of neuropsychological development reflects the natural adaptive process in normal children, where biological maturation, under favorable conditions and responses from the environment, ensures continuous mental development. There is no reason why brain-damaged children would not benefit from the same power of natural development, and this is actually the first mental growth factor that explains generally good outcomes from limited brain injury in children.

However, when we refer to learning disabilities, we precisely mean specific difficulties related to only progressive and relatively late maturation of these nervous systems.

Learning disabilities are quite unpredictable from basic sensory and motor competence. This is another reason to be careful about the linear representation of mental development. Specific learning disabilities also show that there is no biological necessity for the various mental abilities to develop in parallel. Finally, we know from prospective studies that former patients from child rehabilitation tend to retain marks of their specific disability once they become adults, although they can recover from the social consequences of such a handicap.

Learning disabilities also show that late instrumental learning is probably more vulnerable to prenatal abnormalities of cerebral development than early sensorimotor learning. For example, executive intelligence, the type of intelligence that regulates inputs and outputs, as well as emotions and cognition, sensitivity and behavior, appears to be particularly fragile in the development of learning-disabled children.

2) Recovery

Aphasia studies have revealed the process of taking over language functions by the right hemisphere in right-handed children. However, transfer of language functions to the right hemisphere in the right-handed only appears when there is early and massive injury to the left hemisphere.

Many studies have observed that recovery is inversely proportional to age (Vargha-Khadem et al., 1985; Martins & Ferro, 1992). Recovery depends on the neural integrity of the spared left and right hemisphere regions. However most, if not all, left-hemisphere damage results in some language disturbance.

School failure is often dramatic, showing that complex aspects of language, namely the passage from oral to written language, is constantly handicapped after left-hemisphere lesion in children.

Recovery by functional plasticity has its cost, that of competing functions in "overcrowded" preserved areas of the brain. This is why there is no transfer of language functions to the right hemisphere when enough intact matter remains in the left damaged hemisphere (De Vos et al., 1995).

Complete equipotentiality between the two hemispheres, as already foreseen by Lashley in 1923, is only valid for a limited series of functions. Right-hemisphere lesions in childhood sometimes produce language disturbances, as left-hemisphere lesions do. However, unlike left-hemisphere

lesions, severity of symptoms appears not to be dependent on right-hemisphere lesion size (Levin et al, 1996a). Moreover, persistent language-related difficulties predominate in integrated functions such as reading, writing and arithmetic (Levin et al. 1996b). Small children often exhibit motor and cognitive deficits after right-hemisphere lesions, whereas older children more often show attention and behavior disturbances (Ewing-Cobbs et al. 1994). There is only a slight bias in the direction of adult lateralized deficits, with visual-spatial symptoms more prominent than verbal ones (Montour-Proulx, in Braun 2000). Thus, in contrast to what would be expected from an equipotentiality paradigm, left and right brain damage have different outcomes in children. Moreover, recovery shows some limitation of the plasticity for functions hitherto sustained by the right hemisphere.

From the time when the normal child has built an image of himself/herself, and for example speaks about himself/herself, most of the motivation for learning is rooted in a desire to cure oneself of the status of relative inferiority and ignorance. Similarly, the brain-damaged child, if not deprived of interaction with other children, creates an image of himself as overcoming his disability. Many new recovery strategies derive from motivation for growing and healing. They rely on mental representation about ways of maintaining an image of the self as constantly changing and learning.

This fundamental need for growing leads the child to select the kind of goals and behaviors he thinks make him grow, and to reject those which prove unsuccessful. This conceptual option sometimes contradicts therapists' efforts. The healing image of oneself is subject to some decline due to confrontation with reality. Motivation for relearning becomes tempered with impatience and disappointment. At this time, the search for new strategies can be replaced by immersion in a more global treatment. Music therapists, for example, claim that music favors exploitation of preserved neural pathways, thanks to its extended and multimodal span of means of communication. This claim is theoretically interesting, since it takes into account the fact that neither the therapist nor the child has full knowledge of all the available strategies that can help maintain the positive image of the self.

3) Compensation

Compensation is the third mental growth factor that promotes recovery after brain damage. Compensation is concerned either with a complete shift of modality to attain the same competence, such as Braille instead of reading black print, or with new orientation in the learning process, like overtraining particular talents. Children are very keen on functional adap-

tation that is on finding new uses of their motor and sensory systems to relearn differently how to attain a final goal. During development, language offers great opportunities to bypass direct action, even to compensate for deprivation of movement and walking.

The question about compensation is that of the resources the individual can draw from internal energy in order to increase effort to train new skills. Whether it consists in activating unused skills or improving the use of residual skills, compensation does indeed necessitate allocation of increased time and increased attention to the learning process.

The power of compensation can be measured objectively by means of tests for assessing the learning of material that has never previously been used by the child. This ability to learn new things is evidence of the normal functioning of the cerebral regions spared, which, despite the cerebral lesion, have retained their power of specialization. Functional disruption of these regions, as it happens for example during epilepsy or chronic drug intoxication, is sufficient to compromise the specialization process as long as epilepsy or toxic effects remain uncontrolled.

But compensation does not just occur following a functional deficit. A mechanism resembling compensation is at work in the case of individuals with particular talents, whose efforts to improve in one activity are contrasted with lack of interest in another. With Baltes, we can conclude that we have a relatively poor understanding of the functional role of compensation in the development of the normal child. We personally conclude that we even have less understanding of compensation in brain damaged and learning disabled children.

8. Natural adaptive process, recovery and compensation

In contrast to adult rehabilitation, maturation, recovery and compensation are intertwining and parallel corollaries of growth in children. As we have seen, neural network construction does not stop throughout childhood. Brain damage sustained during childhood rarely forces the child to lower his/her expectation, as we can often observe in adults. Social demand for redeveloping language and movement autonomy does not tolerate any compromise in evaluating criteria of success.

Brain-damaged children, with all the remaining years of the growing process, can train abilities sometimes beyond the norm, giving rise to paradoxical talents. For example, acquired speech disturbance or even acquired dyslexia can finally lead to the overtraining of verbal skills. Such a child might later have a tendency to paradoxically choose a profession related to literature.

In children, each nervous functional system has its own schedule of maturation. In a constructivist view of the human mind, each brain specialization has its own time of integration within a comprehensive mode of acting and thinking. Functional loss appears as natural as functional gain, because loss of primitive functioning is necessary for new integrated behavior to occur.

Experience and particularly rich interaction with a highly encouraging environment help build new functional networks into the child's brain. Early transfer of function from an already differentiated area to a less specialized site of the brain can be considered to be a rule, and this functional plasticity is also facilitated by rich experience. However, functional plasticity has its limits and does not occur with no cost. Focalization of brain lesions, related to large spared and highly functional regions within the same hemisphere and within the contralateral hemisphere, is the best predictor for the lost function to reappear. However, children have a wide range of prospective acquisition ahead of them, so that late-emerging complex learning is not guaranteed when early recovery of simple function proves successful.

9. Education and training

So far, we have stressed the child's psychological development from a neuropsychological point of view. We have shown that this development responds to hierarchical brain organization represented by the growth of organic functions, functional systems and instrumental functioning. We have put forth the time schedules for acquiring the expected skills, giving much importance to learning backwardness in the sense of delayed academic acquisition during the school years.

We have also tried to integrate knowledge from the different developmental sciences and to enhance cohesion between the specialized per-

spectives. By stressing learning as representing the major growth factor, we have emphasized the educational role which is partly, but anyway not to the least extent, responsible for the child's experience. To brain organization corresponds learning organization in the environment. The duty of educators is precisely to organize learning strategically in order to present the child with experience and material that meet his/her needs.

Keeping in mind that learning is not only matter of natural adaptive processes but also of compensation and even recovery when necessary, teachers and educators (including parents) have to plan learning objectives. They have to choose individual strategies for this goal whenever education for all does not reveal itself sufficient for a particular child.

It does not mean that educational programs have to be necessarily individualized. But because educator's task and sensitivity is to observe if one particular child learns as much and as rapidly as the other children, turning to and orienting towards individualized programs is part of their job. We would like teachers to retain from developmental neuropsychology that it is their responsibility to prepare comparative observation of the children left to their care. We think that the best way of convincing parents, administrators and therapists that a special program has to be added to regular instruction for a particular child roots in the objective observation of the learning rate. For learning, as we tried to show, has interdependent components, the natural adaptive process, recovery and compensation, in the disabled learner.

10. Specialized therapies

Targeted neurocognitive therapy offers an indispensable alternative to traditional therapy, because it aims precisely at preventing long-term disability after brain damage. With the best conditions of rehabilitation, children show astonishing compensation mechanisms, which assist functional adaptation despite permanent sequel of brain injury.

All these growth factors, which are of great significance in the mental development of brain-damaged and LD children, are poorly represented by the normal developmental curve, are represented even less by a developmental quotient. Only longitudinal and properly timed observation of progress, separately for the different nervous systems to emerge, such as

callosal mind or executive intelligence, can account for the best exploitation of all the means of recovery. We can only recognize the limits of the recovery process when all the opportunities have been taken for the best rehabilitation possible. Even if careful and comparative follow-up takes place during growth, final appraisal of recovery has to await adulthood, after the best rehabilitation measures have been taken, without respite, in order to insure the greatest vocational and economical independence as possible.

Part III. "Signature": an original essay.

1. Criteria for prewriting analysis

If the child's first pronounced word very often refers to his/her mum or dad, the first written word concerns his/her own first name, which we call signature. We had the opportunity of observing 100 children aged four to seven while they accomplished a praxic task, i.e. miming usual tool use. During preparation of the setting (video recording), the child was asked to write down his/her first name on a white A4 (30 x 20 cm) sheet of blank paper presented horizontally, aligned to the square table edge. So we had in hand 100 signatures obtained from children supposed to learn to write (of course, whenever one child did not know any letter from his/her name, he/she was asked to draw him/herself (self-portrait instead of signature).

At first glance, it looked impossible to categorize so many different graphic traces. However, it appeared to us as a demonstrative neuropsychological exercise to build the more precise developmental rating scale regarding signature. The way we will do it explains what precisely a neuropsychological analysis is. Furthermore, we now think that this essay will interest education professionals.

We would like to first express a warning related to the use of the results of such an experiment. Much further analysis is needed before we can use an experimental tool like signature as a real developmental test. We would need to obtain much more results, namely of approximately 100 children for each six-months range of age, since starting to write takes place suddenly as soon as the child masters the pencil and becomes curious about letters. For each age group, or any other group category (sex, oral lan-

guage, only child, eldest child or rank among siblings, kindergarten experience, training from parents, and so on), we would need to study the meaning of signature by correlating this ability with other observed variables. Signature is a very peculiar symbol, so much depending on self presentation that we should record personality variables in order to precisely know what it means to be willing to exercise one's own signature.

However, this was not our goal. The two comparative variables at our disposal was age and ideomotor performances, the miming of everyday tool use. The challenge was the following: that normalization of "signature" was possible would be evidenced by its validity regarding age and praxic development, nothing more. To attain this goal, we think neuropsychological developmental theory of first importance. By doing so, we think we will emphasize what is typically neuropsychology in comparison to other psychoeducational theories.

First variable: referring to coordinates

The child sits in front of a space at his/her disposal for signature. The blank space has the shape of the sheet of paper. We carefully aligned the sheet with the coordinates. This means that the sheet border close to the child was parallel to the table edge. Tactually and visually, this is supposed to provide the child with a strong sense of the coordinates, the axial and transversal or, by extrapolation, the symbolic vertical and horizontal axes. Taking this sense of coordinates into consideration would mean that the child will orient his/her signature in relation to the sheet of paper. Writing is a graphic behavior that fills in an imaginary line on the sheet of paper. Any knowledge about the letters forming one's own first name let imagine a certain line length. Even if aligned with the coordinates, starting near the right edge when one writes from left to right does not leave enough room for the letters to form a line. To sum up, signature demands to fill in only one line parallel to the horizontal axis, while preserving enough space for the whole name to be written down.

Second variable: letter size

In his famous book "Teach your baby to read", Doman proposes to train babies recognizing word forms that are written in the most apprehensive manner. He suggests to present the child with short words written in red and in letters of minimum 100mm. height. This is supposed to be done in accordance with the child's immature visual perception for differentiating small and oriented forms. Keeping distance from Doman suggestion,

we nevertheless think that letter size is related to two important capabilities that develop in kindergarten: the visual discriminating and the motor executing abilities. Writing small letters, for example 10mm. high, is the privilege of digital motricity whereas 40mm. letters are best executed with the arm. To sum up, letter size in signature is supposed to reflect the differentiation of the manual abilities from global arm, through medium wrist to fine finger movements.

Third variable: letters knowledge

Pseudo writing represents a developmental stage during which the child imitates writing by drawing letter like forms. At that time, the child also pretends to read, following lines with his/her finger and inventing text. The third variable is intended to separate pseudo writing from correct letter writing. A correct letter is a recognizable form, whatever its orientation, even mirror. Of course children with short names are advantaged in comparison with children with long names. This is why we take the percentage of recognizable letters into account, i.e. the number of correct letters divided by the number of expected letters. To sum up, letters represent alphabet learning and definite disambiguity of writing from pseudo writing.

Fourth variable: letter case

Writing capital or small letters, or even knowing the difference, and using this difference regarding letter place, represents both an alphabetic and motor progress. With small letters, we again meet the same progression as seen in letter size. However, the movement for realizing small letters differs from the one for capitals. A tonus relaxation is needed in order to form round letters in comparison with "square" capital letters. Script is an intermediary form of letter insisting on separate letter-sound relationship, whereas small letter writing is intended to link letters graphically. Tonus relaxation follows the rules of proximo-distal differentiation, so that relaxed fingers represent the ultimate stage of relaxation. Beside tonus, small letters introduce a dubbing of the alphabet and the learning of capital-small letter's correspondence. Thus the use of small letters reflects a progression in both linguistic and muscular control. It ideally represents the synthesis of the auditory and the motor modalities, since lexicon differentiation meets proprioceptive differentiation. Written language precisely finds itself at the crossroad of different modalities, like the visual and the auditory ones in reading. Different letter case use therefore means a decisive step in written language learning. With the exception of the first letter

(see variable 6), the rate of small letters is considered as a developmental feature of signature.

Fifth variable: static and kinetic inversion

This is the most controversial variable since it was supposed as the root of dyslexia. Strephosymbolia, as Hinshelwood called it, was the phenomenon of reversing the letter orientation. However, inversion also occurs in the letter string (PRA for PAR, for example) or in the direction or writing (RAP for PAR). Therefore, we have to consider separately the inversion of letters and the inversion of the writing direction. Mirror writing appears as an exception to inversion, the systematic (and somehow skillful) writing from right to left with all letters reversed. Considering the privileged symmetrical organization of the brain, mirror writing actually is skillful. It is just not accepted by social convenience because the reader cannot profit of the same symmetrical bias as the writer. Because we have to take into account the whole lateralization problem in the case a child writes in mirror, we do not count as an "error" the mirror writing. If we would like to know more about the origin or mirror writing at this age, we should have carefully recorded handedness for writing and handedness as a whole, which we did not do. However, there are cases of confusion. In the lightest cases, children are fully aware of letter orientation and are only confused about writing direction (RAP for PAR). In respecting letter succession, these children show firstly that they have achieved a stage of letter orientation and the problem lies in the confusion between letter and reading orientation. More erratic is the case of static (only one letter) or dynamic (order of the letter in the string) inversion. In this case, we are facing a kind of letter puzzle where each piece is randomly assigned place and orientation. To sum up, we are giving advantage to the child's writing that respects both letter orientation and letter string succession. When the first name is written in mirror as a whole, conditions are met for direction respect. Immaturity reveals itself as the confusion of orientation, not as the respect of orientation regarding the whole name.

Sixth variable: first letter marking

Does the child know what he/she is doing when writing down his/her name? The same way the first name is the delegate of the child's person, the first letter is the diplomat for this representation. We think that this re-presentation is a gain in the meaning of the writing as a whole. Have a look at your own signature and, please, do not be ashamed if the first

letter appears as over dimensioned. This is you. We therefore think that the size, the case and any distinctive feature of the first letter in comparison to the following ones reveals an aspect of the writer as a writing person, not only as a child playing with letters and assembling letters to please the adult. To sum up, marking the first letter represents the symbol of mastering writing and of signing one's own written work.

Seventh variable: linguistic link between letters

The grapheme-phoneme relationship appears as a fundamental capacity for written language. The combination of auditory (hallucinated) input with visual input forms the basis of written language. Oral language therefore assures some type of control over the visual inputs. Furthermore, oral language is projected on the writing task in order to assure the link between the successive visual inputs. The seventh variable investigates the most linguistic component of signature, i.e. the linguistic link between the elements (letters), whatever their production one by one. Each time two letters are correctly linked counts. Again, the result is expressed in percentage to give equal chance to children with long and to children with short names. The child who writes in mirror or who inverts individual letters is not penalized here. However, the child who misplaces letters in the string receives penalty. To sum up, rank order of letters witnesses the ability to control linguistically the ability of writing. We consider this typical linguistic ability as a core acquisition for meaningful writing, referring to time rather than space integration.

2. Experiment: decoding first name writing

Is the method of allocating bonus to each of the signature feature follows:

Calculating the signature index

Signature is allowed the following points for the following features:

Points features

Variable 1. Referring to coordinates

- 0 no recognizable writing line (several lines)
 and no letter
- 1 writing line sloping more than 10 degrees and/or letter rotation (do
 not count reversals here)
- 2 writing line sloping more than 10 degrees
- 3 one line, aligned to coordinates

Variable 2. Letter size

- 0 smallest letters taller than 35mm.
 or no letter recognizable
- 1 smallest letter's height from 11 to 34mm.
- 2 smallest letter's height from 7 ÷ 10mm.
- 3 smallest letter's height from ÷ 6mm.

Variable 3. Letters knowledge

- 0 letter like writing, no letter recognizable
- 1 from 1 to 49 % recognizable letters
- 2 from 50 to 99 % recognizable letters
- 3 100 % recognizable letters

Variable 4. Letter case

- 0 no small case letter
- 1 from 1 to 49 % small case (included first letter)
- 2 from 50 to 99 % small case (included first letter)
- 3 100 % small case (first letter excepted)

Variable 5. Static and kinetic inversion

- 0 static as well as kinetic inversion (example: T\$R pour TRE)
 or no letter
- 1 static or kinetic (ex : TR\$ or TER for TRE)
- 2 inverting writing direction (ex : ERT for TRE (letters oriented))
- 3 no inversion.

Variable 6. First letter marking

- 0 first letter smaller than the following ones, or no letter

- 1 apparent height equality between letters
 - 2 first letter capital, some or all others in small case
 - 3 first letter capital plus other distinction from others by height or traits
- Variable 7. Linguistic link between letters
- 0 no link respected or no letter
 - 1 from 1 to 49 % respected links
 - 2 from 50 to 99 % respected links or missing/added letter
all links respected

Nota bene: from the variables above, only three of them are continuous variables: letter size, letter case and first letter marking. The other variables are discontinuous and rather show categories of response, which always can be put in question.

Calculating a signature index

Signature index = sum of variables 1 to 7

Index minimum = 0

Index maximum = 21

Correlating signature with independent variables

In order to test Signature's validity, we recorded the following independent variables:

- sex
- preschool (EE1 and EE2) and school degree (1P)
- age in months and age groups, 4 , 5 to 5 ½, 5 ½ to 6, 6 to 6 ½, 6 ½ to 7, 7.
- a linguistic index: object naming (below in French « nb.deno. correctes»)
- a praxic index: object use pantomime (below in French « nb. gestes corrects»).

Results

There is no sex difference neither in the mean score nor in the variation.

	N	Mean	Standard Deviation	Minimum	Maximum
Boys	50	15.66	5.009	0	21
Girls	45	15.98	5.154	0	21

Table 3. Signature. Comparison between boys and girl's results.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.392	1	2.392	.093	.761

Table 4. ANOVA statistics for sex difference.

Signature scores develop regularly and significantly with school degrees (fig. 18) as well as with age (fig.19).

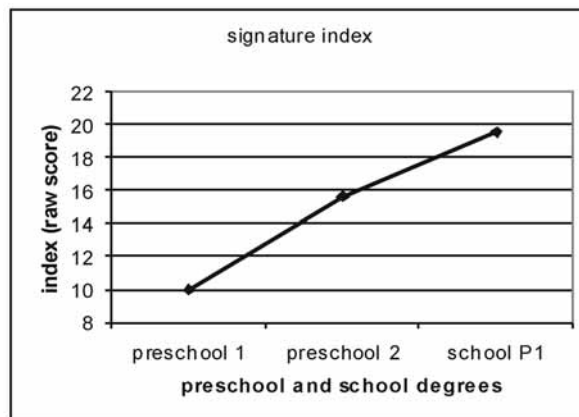


Figure 18. Development of Signature mean scores with school degrees

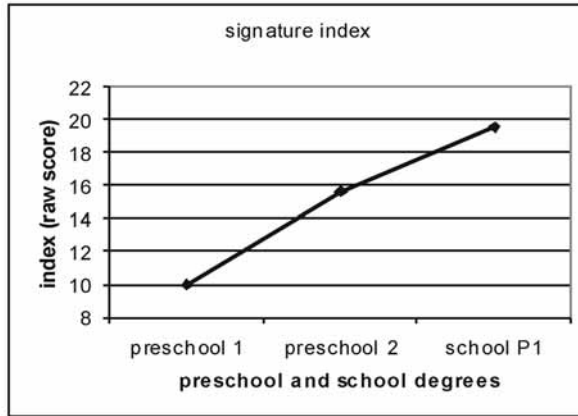


Figure 19. *Development of Signature with age groups.*

Table 5 shows the correlations Signature holds with age, sex, and both the linguistic and praxic variables.

	AGE	SEX	NAMING	GESTURE	SIGNATURE
AGE	1	.160	.343	.516	.684
SEX		1	-.111	.067	.032
NAMING			1	.439	.297
GESTURE				1	.424

In bold: Correlation is significant at the 0.01 level (2-tailed).

Table 5. *Correlations of Signature with age, sex, linguistic (naming) and praxic (ideomotor gesture) index.*

It clearly appears that Signature is a procedure that does not record results at chance between the ages of four and seven. School degrees and six months age groups greatly influence Signature with a ceiling effect at age 7.

Validity of Signature is also confirmed by cognitive independent variables, a linguistic (NAMING) and a praxic (GESTURE) index. However, less than 20% of Signature score is explained by the cognitive independent variables.

Table 6 and 7 offers the conversion of raw scores into prewriting quotients.

To sum up, Signature appears as a simple procedure reflecting pre-writing development, greatly depending on age and (pre)school experience (In our country, primary school starts in August and children aged 6 ;0 to 6 ;11 on June 30th. are automatically included in 1P) . Furthermore, Signature somehow correlates with cognitive variables, more of the praxic than of the linguistic nature.

So much depending on training gained in the family and in the school, Signature has to be considered as a culture-dependant in dice and should therefore be used with much caution. It should never be interpreted as an isolated sign. Nevertheless, Signature offers a reference in writing learning and can be compared with the development of other graphic and writing abilities.

As far as relationships between neuropsychology and education are concerned, Signature perfectly illustrates, we think, the numerous components intervening in the writing act at school beginning. Each time we look at early learning from the neuropsychological point of view, we cannot but be amazed to see how easy such multifaceted learning is achieved for the majority of the children. Signature offers a specific tool for evaluating learning disabled children who particularly suffer from writing difficulties.

We are pleased to offer the method of our analysis in order to extend the experiment. In the case of different alphabet and of different educational practice, we would be mostly interested in knowing the validity of the procedure in different cultural background.

François Gaillard – Argyris Karapetsas

Index Signature	Prewriting quotients		
	Preschool 1 EE1	Preschool 2 EE2	1P
21			110
20			100
19		126	96
18		118	
17	116	110	80
16	113	100	
15	110	95	65
14	109	87	60
13	106	79	
12		70	
11	102		
10	100		
9			
8	95		
...			
4	85		
...			
0	75		

Table 6. Prewriting quotient regarding (pre)school degree.

Index Signature	Prewriting quotients			
	Age 4 ;0 – 4 ;11	Age 5 ;0 – 5 ;11	Age 6 ;0 – 6 ;11	Age 7 ;0 – 7 ;11
21			120	110
20			115	100
19		120	105	95
18		115	100	
17	117	112	95	
16		108	88	
15		105	82	65
14	111	102	75	55
13	109	100		
12		95		
11	105			
10				
9	100			
8		82		
...				
4	90	65		
...				
0	85	56		

Table 7. Prewriting quotient regarding age groups

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