

**Tan's Metamorphosis Concept of speech-language development.**<sup>1</sup>

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**Abstract**

Our paper provides support for Tan's Metamorphosis Concept of early speech-language development, conceptualised as a change in activation balance from the right (RH) to left hemisphere (LH) of joint affect-motor (AMPs) and affect-linguistic paradigms (ALPs). These are RH neural networks in their earliest forms, changing into LH networks, activated for elaboration of language. Several lines of research lead towards the idea that the RH plays a dominant role before the three-word-sentence stage. First many findings point to RH significance for affect in verbal and nonverbal pragmatics, i.e. affect in body language and speech; there is RH dominance for emotions, especially for aspects that are automatic expressive and autonomic, and often for the preconscious aspect, as well. In infancy these aspects prevail over formal, conceptual and deliberative LH aspects. Second, in infants there is also a multimodal object learning process, an RH function, including word-sound and its accompanying affect. Third, electrophysiological work points to early LH activation for formal speech sounds, to prevalent RH activation if what is concerned is the difference between known and unknown words, and dichotic listening tests point to LH dominance from age 4 only. Fourth, lesion and split-brain studies suggest that the child and adult RH contain old speech remnants, and in early brain damage after age 2, beginning speech can use these remnants to develop elaborated grammatical language, though usually not as well as when there is a normally developed LH. Fifth, there is research suggesting the close connection of early motor function and speech

**Introduction**

There has been very little electrophysiological and neuroimaging research into speech development in infancy for the obvious reason that conducting experiments on children at that age is extremely difficult. Theorizing about neurological development in this domain comes from electrophysiological and dichotic listening studies, the nosology of developmental language disorders and brain lesions, studies of people with a split brain, and speech perception studies.

There has been some theorizing, but very few people have proposed a complete neurolinguistic concept, i.e. a concept entailing the neural networks for speech and motor function in ontogenesis, developmental linguistics and the role of speech-language in the child's affective life. To our knowledge, one of those who did this was the late Xavier Tan, a Dutch child neuropsychiatrist. He presented his hypothesis, which he called *the Metamorphosis Concept* in an article he wrote in Dutch in 1990. Another was John Locke, a developmental psychologist and linguist, who in 1993 proposed a concept of language development that in some aspects overlaps with Tan's. Tan and Locke were not informed about each other's hypotheses. Bates et al. (1992, 1997, 1999) suggested that the RH plays a role and that neural change is going on in young children when their language develops; their work on brain-lesioned children supported this hypothesis.

The present authors worked with Tan for nearly 25 years. A typical saying of his was: 'Science creates categories, which do not really exist in life or art'. In 1982 Tan founded the Foundation for Developmental Dysphasia and was the leader of the treatment team. He prepared an English translation of his book that came out in Dutch (2005), but his untimely death in 2003 prevented publication.

Tan's Metamorphosis Concept will be presented, citing excerpts from his writings. We will comment on the most important aspects of this concept in the Discussion.

**The Metamorphosis Concept: affect-motor and affect-linguistic paradigm from right to left hemisphere.**

What follows is Tan's explanation. The Metamorphosis Concept is a concept of speech-language development which aims to 'translate' speech-language phenomena and processes into neuronal terms. The word metamorphosis, meaning transformation from one form into another, comes from Ovid's *Metamorphoses*.

The background of my hypothesis is – beyond clinical observation – Greek art and philosophy, which were based on the concept of chaos versus cosmos, used as metaphors for my neurological hypothesis. *Chaos*: an ever changing, undefined, unmeasurable world with seemingly random impressions, causing a constant state of anxiety. *Cosmos*: a world of order, patterns, measurability, where everything functions perfectly and can be

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perfectly understood. Rooted in this way of thinking were two aesthetic Greek principles: 1. The analysis of forms into their component parts, based on *symmetria* (commensurability) and *rhythmos* (pattern). 2. Representation of the specific in light of the generic. In my concept it is the search for typical and essential forms (cf. the first AMPs and ALPs).

According to J.J. Pollitt (1972), whose work is the source of the ideas that follow, there is remarkable development in 'kouroi' ('kouros' is the Greek word for 'male youth'; the plural is 'kouroi'). These sculptures of a naked, standing male figure, were made in Greece from 650 to 480 B.C. The kouros was a heightened representation of human consciousness, evolving from a symmetric, formal and impersonal form in the Archaic period to a personal, expressive, living one in the early Classical period. In fact there is a development from *symmetria* to *rhythmos*. Instead of the stiff postures of the Archaic period, the later figures are in what is called *contraposto* posture, a relaxed asymmetrical pose of the human body, in which the shoulders and hips are turned in different planes. This shows bilateral coordination allowing for axial body midline crossing (see further general remarks in the Discussion).

*Symmetria* is easier to understand than *rhythmos*. In psychoanalytical thinking, the anal stage is *symmetria*. The colour of the relationship of the child to its parents in this stage is 'symmetrical', i.e. equivalent, in contrast to the oedipal stage, when the child becomes aware of gender differences and asymmetry sets in. Madame de Maintenon said of Versailles: '*Ici on meurt en symmétrie*', suggesting a static culture in a symmetric architectural setting.

Being 'higher' in the hierarchy of development, being more complex, may explain the fact that *rhythmos* is more difficult to understand than *symmetria*. It is no wonder that the term *rhythmos* is practically unknown nowadays. Literature on this subject is scarce and hard to find. The only texts that come to mind are Aristoxenos' *On Rhythmos* and the studies written by Petersen (1917) and Pollitt (1972).

In my Metamorphosis Concept I assume that the human organism's development is based upon this same principle, from chaos to cosmos, upon this need for order. We know from embryology that the developmental stages of phylogeny (the evolution of a species) pass through ontogeny (development of an individual) in rapid succession. It is my firm belief that development from *symmetria* to *rhythmos* is repeated in the development of praxis, speech and language, at least in its earliest stages. The transition of speech-language and praxis from the RH to the LH also supposes a change in state of mind and consciousness, linked to hemispheric involvement, finally ending in a dynamic system of balanced interhemispheric cooperation, an integration of asymmetrically controlled functions.

*A brief description of the historical background of hemisphere specialization.* European aphasiology, starting with Broca (1824-1880) and Wernicke (1848-1905), put forward the idea that specific lesions may impair the ability to communicate. However, Jackson (1834-1911) wrote: 'To locate the damage which destroys speech and to locate speech are two different things'. Jackson was the first to mention the speech automatisms involved in aphasia and the first to point out the influence of emotion on the 'remnants of speech', and he learned to differentiate between voluntary (propositional) and emotional (automatic or involuntary) speech. Early in the twentieth century a movement emerged (Marie, Goldstein, Lashley), that moved away from the specific cerebral localization theory.

During the Second World War and afterwards, there was a revival of the cerebral localization theory, led in the Soviet Union by Luria, and in the United States by Penfield a.o. Split-brain operations performed in the Sixties (Sperry, Bogen and Gazzaniga) provided a wealth of information, especially on hemisphere specialization and the functions of the corpus callosum (CC). Less bloody were the dichotic listening tests done by Kimura (1963), which made it possible to demonstrate the functional asymmetry of the hemispheres.

The changing terminology – specialization of the hemispheres instead of dominant; 'major' hemisphere (left) versus the non-dominant 'minor' hemisphere – in these matters seems to be a reflection of the prevailing conceptions.

The elegant auditory tests of Kimura (1963), the split-brain experiments of Sperry in the Sixties and the work of Molfese (1972) on asymmetric speech perception at birth should have led to a total revision of the concept of speech-language development. Yet few questioned why this had not happened by the end of the twentieth century. The introduction of a new concept of speech-language development – the Metamorphosis Concept – has to be seen against this historical background.

Over and over I have asked myself how linguistic data should be 'translated' into neuronal terms. We need to clarify some basic ideas in order to understand the Metamorphosis Concept. Speaking involves the ears (hearing speech), the brain (hemispheres, corpus callosum) and the voice/speech apparatus (vocal chords, speech musculature, palate, tongue). Moreover, in my concept, *determinants of speech-language development* are a child's caretakers who share with it: 1. relation; 2. bodily contact; 3. movement; 4. imitation; 5 play.

*Some words on the role of the right hemisphere (RH).* Explaining the functions of the RH is as difficult as describing the fragrance of Guerlain's Jicky perfume, the sight of a painting by Mondriaan, the sound of the Igor

Stravinski's *Rites of Spring*, the taste of Chateau d'Yquem, or the texture of velvet to somebody who has never encountered them, or explaining *Finnegan's Wake* by James Joyce or a film by Antonioni in three sentences. It reminds me of a child of four, who can tell a simple story, but whose language becomes incoherent when telling a story with highly ambivalent or emotional content. It is easier to speak about the RH using a wealth of redundancy, like an old-fashioned kindergarten teacher telling a fairy tale.

It is impossible to explain the functions, the characteristics, the moods and the state of mind of the RH in a formal, academic way. One cannot be forced to speak in classical terminology about phenomena that do not fit into a classical concept. This same dilemma exists in quantum mechanics. The want of a clear concept of development may be caused by these problems. Music and everything connected with movement of the body (rhetoric, acting, dancing, athletics) has been removed from the study of the humanities for too long.

Table I. Hemisphere specialization in adults

Left Hemisphere	Perception	Right Hemisphere
Analysis-synthesis	<b>visual</b>	at a glance; Gestalt recognizes faces perceives whole patterns
Analysis-synthesis	<b>auditory</b>	tonality, prosody, rhythm
Analysis-synthesis	<b>smell, tactile sense, taste</b>	recognizes instantly
Chronological, sequential	<b>time</b>	global, dreamlike, floating
Formal (lawyers, police)	<b>speech-language</b>	colloquial language, poetry, baby talk  jabber talk, exclamations onomatopoeia, swearing
Rational, causal, inner language Words: symbolic	<b>thinking</b>	intuitive, in images (eidetic) words: multisensorially connoted music, creativity, mathematics; spatial constructive orientation
Verbal modalities of motor action Daily movements	<b>motor phenomena</b>	affective modalities motor persistence athletes, dancers, actors, mime

For schematic simplicity we can say that in the adult the following 'functions' are more RH than LH: the RH has another 'state of mind', another time experience, recognition of faces, body awareness, etc. (see table above for details). Most of these qualities or abilities have to do with the senses, motion, speech-language, music, art and learning. RH functions are probably closely connected to what Konrad Lorenz (1970) called 'imprinting'.

Speech and language, movement, music, art and even learning are intricately connected to culture. When one is 'in' the RH, one is in another state of mind, another form of consciousness. But once one becomes aware of this, one is 'in' the LH, in the state of mind that we normally know as 'being conscious' (thinking with inner language, a working memory function). To put it differently: each hemisphere has its own form of consciousness.

*Metamorphosis refers to neural changes.* Specifically speech and motor function are involved in the shift to the LH which I have conceptualised as an interrelated change of the affect-motor paradigm (AMP) and the affect-linguistic paradigm (ALP). One may translate the paradigms neurologically as engrams or neural networks. To understand the terms affect-linguistic and affect-motor, we must first understand what the words 'affect' and 'motor' mean.

In science, *affect* or feelings have never been a serious issue. The minute study of affective development, based mainly on psychoanalytical theories (Sigmund Freud, Anna Freud, René Spitz, John Bowlby, Margaret Mahler, Selma Fraiberg) is nowadays often dismissed as 'old-fashioned'. For a wide range of reasons, it is no longer fashionable to speak highly of psychoanalysis. I have chosen the English word 'affect', used in psychology to mean what in colloquial language would be called 'feelings', to underline the close relation with the German word *Affekt*, found in rhetoric and music. Feelings connected to words and actions are personal; for the infant and young child they are 'mine'.

By *motor* (function) I mean cortically controlled praxis (actions) and body language, not elementary motor functions such as muscle tone. All kinds of motor activities seem ‘natural’ and ‘universal’, while in reality they are often personal.

1. *The affect-motor paradigm* (AMP) is easier to describe and to understand than the ALP. The AMP neural networks represent multisensorial and affectively connoted basic forms or prototypical building blocks, the essence (*rhythmos*) of several motor actions (sitting, standing, walking, grasping, pointing, waving goodbye, and the like).

Although many people think that the senses function in an autonomous way, objects\* are learned and remembered with a range of sense qualities, in what is called a multimodal way. It is quite plausible that there is synaesthesia at birth (Maurer and Mondloch, 2005), a condition that usually develops through learning into functional multi- and uni-modality. Infant physiological synaesthesia is an aspect of RH consciousness, closely connected to movement and affect (smell and texture are intimately connected to the mother's face, skin and clothes).

As the significance of the German word *Affekt*, as used in baroque music, is very close to the connection between movement and the multisensorial and personal affective aspect, this term has been chosen as a name for these neural networks: the AMPs.

Learning to walk is usually achieved through frequent trial and error in a playful setting. At first children walk with a wide-legged gait, then all of a sudden, they walk. The human gait is so personal that children can recognize the ‘step’ of their caretaker when they hear it; the AMP is also related to the individual’s personal way of walking. Kittens also engage in playful tumbling and their sitting and walking are clumsy, then all of a sudden they ‘sit’ in that characteristic graceful and dignified cat manner of sitting.

In my view, the early AMPs (in the RH) will be ‘transported’ to the LH. In the ‘analytic’ LH (after the RH stage) motor actions are further differentiated (elaborated). Walking, for example, turns into hopping, skipping, running, etc. and grasping, squeezing, pulling, throwing develop into differentiated manipulation of objects and sequences of actions become possible. In the analytic LH the AMP is also elaborated to ‘verbal’ modalities of walking: jumping, hopscotch, running, and so on.

2. *The affect-linguistic paradigm* (ALP) is just as difficult to describe this as it was to describe the sensations listed in the section on the RH.

Things become easier when we ask: what is it all about? A young child starts to ‘think’ in images, textures (touch), sounds and smells, and only later does it use ‘language’. Analogous to the notion of AMP there is a coming into being of early RH ALPs. Schaerlaekens (1977) and Schlichting (1996) published a list of ‘first words’. For forty Flemish-speaking children these were the equivalents for daddy, mama, bye-bye, wee-wee, poo-poo, beddy-bye; words for people, food, actions, animals, vehicles, and the noises they make (e.g. ‘vroom’); toys and transitional objects, clothing and body parts; social responses (hello, bye) and pointing (deictic) words (here, there).

The ALP is the model for expressions used by toddlers: ‘daddy car’ or ‘me too’ are examples of RH affectively-controlled expressions. The ALP begins as affect-laden word combinations signifying what is personally significant (people and objects, that are affectively linked to each other), for example ‘daddy’ and ‘car’ belong to each other. I believe that the number of early ALPs is restricted: ‘going with’ (not wanting to separate); ‘me too’ (I also want to have or do this); ‘mine’ (this is mine); ‘not me’ (I do not want this); ‘daddy away’ (daddy is not here). An ALP consists of a two- or three-word phrase, with a clear multisensorial and affective connotation such as ‘daddy car’ or ‘with daddy car’. Frequently they express an important theme (separation anxiety, love, hate, triumph). ALPs can be compared with micro-ideas, connected with feelings (affect) and (multi) sensorial sensations. However, these are not ideas like those of Plato, unconnected with feelings. Especially after the early verbal one-word stage, in the ontogenetic stage of two- to three-word sentences, there is a transition from the RH towards the LH. In the stage of the three-word sentence these micro-ideas (ALPs) can, with the transition to the LH, be elaborated into more complex forms, new and more complex neuronal networks. In this stage we see considerable progress in grammatical elaboration, for example ‘I go with my daddy by car’. Gradually the three-word sentence and its extensive derivatives will be dissociated from its multisensorial connotation and feelings (affect). This development is summarized in Table II.

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Table II: The neurolinguistic division of speech-language development according to Tan

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THE RIGHT HEMISPHERE STAGE	a) prelinguistic (biological stage 0 to 6 weeks): vocalising 6 weeks to 4 months; babbling without vowels 4 to 6/7 months b) preverbal stage, canonical babbling 6/7 months to 10/11 months
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\* objects can be physical objects, people, faces, behaviour, animals, social situations, etc.

	c) early verbal stage 1 to 2 years: holophrases with gestures 10/11 months; holophrases without gestures 12 months; one-word phrases 14 months; two-word phrases 2 years
THE TRANSITIONAL STAGE	Intrinsic development of the three-word phrase (Elbers, 2000), 2.5 to 3 years: a) linking (adding) at the beginning of the sentence 2.4 years; b) varying before 2.6 years; c) linking/adding after 2.7 years; d) varying, after 2.8 years. Thereafter a word will be adopted from 'the other'. The ALP starts passively before this stage and becomes an LH function when sentences become more complex.
THE LEFT HEMISPHERE STAGE	Extension stage, grammatical development, 3 to 5.5 years; from sentence to story-telling.

Usually speech-language development is restricted to a chronological description. According to me it is more useful to consider speech-language development against the background of general theories on development and the neurological-ontogenetic transformations that accompany the developing elements of speech-language. My concept is different from the one David Crystal gives in *The Cambridge Encyclopaedia of Language*. For me, everything before canonical babbling is pre-linguistic. The canonical babbling stage marks the start of language use and can be called preverbal. Moving from one stage to the next involves a corresponding shift in the neural networks from the RH to the LH.

*Neuro-anatomic transformation (metamorphosis)*. When speaking develops, some 'motor' axons 'accompany' the 'speech' axons from the RH to the LH. In other words, axons of the ALP in the RH go through the CC to 'target' cells in the LH, accompanied by axons of the AMP. I imagine – in light of current knowledge this seems quite acceptable – that in the beginning many callosal fibers cross the midline to allow this process to occur. Once walking is automatized, a reduction in the early 'walking' fibers takes place, so-called axonal retraction, an efficiency principle. It is more efficient if the RH can create a gestalt-like sitting or walking paradigm. Motor axons 'guide' the 'linguistic' axons to their target cells. A schematic cross section of the CC will depend on age: at the age of one year, I assume the corpus callosum will contain more 'motor' axons than 'speech' axons, whereas a cross section at 2.5 years has more speech axons than motor axons. The configuration in cross section has undergone a metamorphosis. It is on the basis of these changes, among others, that I have called my concept of speech development the Metamorphosis Concept.

#### **Discussion: Experimental support for the Metamorphosis Concept**

Both large hemispheres are needed in speech-language acquisition, but the brain areas active in speech-language acquisition in the first years are not the same as the ones involved later (Bates et al., 1992). The changing relationships between affective, motor, and speech-language aspects are reflected in a process of neural changes, notably axonal retraction and synaptogenesis with new connections. According to Bates these neural changes are not age-dependent, but instead depend on what stage the child's speech-language is in, the task that needs to be fulfilled, and whether the child is familiar with it.

*General remarks about typical ontogenetic change in brain function and networks*. In their studies of young children, Chugani et al. [1986,1987,1996] saw that the metabolic activity in the brain reaches a high level at 9 to 10 months and a peak at approximately 4 to 5 years of age, after which there is a decrease, at the time the consolidation of the LH language stage has been reached. This metabolic activity begins first posteriorly and reaches at 9 to 10 months the frontal areas. At 9 months there are signs that the long-distance connections between the brain areas are ready (EEG-coherence studies). At 9 to 10 months an infant sits without support and is in the canonical babbling stage; object permanence starts.

Between 10 and 24 months, with increasingly active vocabulary, pointing with joint attention, and symbolic play, according to (Huttenlocher 1979, 1990) the density of synaptic connections within and between cortical areas at last reaches its peak in the frontal cortex.

From the third until the sixth year the LH shows an increase in frontal-occipital EEG coherence and an increase in the left frontal-temporal area. There is very little change in the RH during this period (Thatcher 1987, 1991).

In discussions on language development, considerable attention should be given to the CC. Here we need to be brief. The CC is immature (unmyelinated) in the first years and delayed maturation may lead to what the first author has called 'developmental interhemispheric disconnection'; CC agenesis is the congenital form and leads to language delay (Ramaekers and Njiokiktjien, 1991). In children with a developmental language disorder Fabbro et al. (2002) showed a CC transfer deficit.

*Is language 'domain-specific' or 'modular'*, in other words, is it an autonomous function processed, generated and developed in a separate neural network? Some children can be non-verbally retarded and at the same time have seemingly well-developed formal speech, for example in NLD (nonverbal learning disability, Rourke, 1990). Considered more closely, speech-language development is influenced by non-verbal functions such as spatial insight, time awareness, object knowledge and motor functions; these are needed for language to develop. Three-

to four-month-old infants use multimodal information to imitate speech sounds; the multimodal nature of speech sound is significant for speech perception and production (Legerstee, 1990). fMRI studies show that receptive speech processing is not restricted to unimodal auditory regions; remote regions are also activated (Dehaene-Lambertz et al., 2006). The domain specificity of language is therefore limited and not absolute.

*Hemisphere differences.* Before and at birth the hemispheres are asymmetrical in size and form, and react electrophysiologically differently to speech and environmental sound. There is no hemispheric equipotentiality. Individual neurons in the speech cortex show differences as well. Scheibel et al. (1985) found cell differences in the frontal speech cortex (Broca), suggesting that these structures in the RH (in layer III) 'lead the LH' in the first year of life: they are ahead in maturation compared to the homologous area in the LH. In their studies of the same layer III in Brodmann area 45, Hayes and Lewis (1996) found left-right differences (in somal size and dendritic arborization), giving rise to the speculation that both sides of the brain are used in the initial stages of language acquisition.

At birth the RH undergoes more rapid maturation than the LH. This maturation difference is related to the functional capacity of the infant. Chiron et al. (1997) state in an article that the right brain hemisphere is dominant in human infants.

It is now accepted that there is RH significance for affect in verbal function – emotional-prosodic aspects – and nonverbal pragmatics, i.e. affect in body language. In adults supra-segmental speech-language elements such as rhythm and prosody are processed by the RH (Weintraub et al., 1981; Ross et al., 1979, 1981). There is general RH dominance for emotions, especially the automatic expressive and autonomic ones, and often for their pre-conscious aspect (Gainotti, 2005). In infancy this aspect prevails over formal, conceptual and deliberative left-hemispheric aspects. Schore (2003) in recent articles stresses the development of the right brain and its role in early emotional life. For other reviews of adult RH functions, relevant to our subject, see Gainotti (2005) and Mitchell and Crow (2005).

Newborns can visually recognize the shape of an object that they have previously touched, though this only happens when the object has been touched by the right hand (Streri and Gentaz 2003). In infants there is also a multimodal object learning process, including the word for the object and the accompanying affect. Intersensory redundancy facilitates infants' learning (Bahrick and Lickliter 2004). Multimodal integration seems to be an RH function, especially in childhood (Goldberg and Costa, 1981; Banati et al., 2000); the RH may also have a synaesthetic function at birth. According to Rourke (1995) NLD is an RH deficit syndrome, whose symptoms and developmental course are a problem in multimodal and coherent functioning. Cortical areas for intermodal functioning are larger in the RH than in the LH; there is more white matter in the RH, expressed in more interregional long-distance connections. Functionally, Dubrovinskaya et al. (1993) were able to show this with EEG coherence; the way the RH processes information is more modality-independent than that of the LH.

Thus speech-language development starts as a gestalt-like and emotional-prosodic interaction, mainly based on RH and subcortical mechanisms. We can therefore assume that the RH plays a relatively large role when infants process prosodic speech and target words.

*Is there a developmental shift of the speech-language networks from right to left?* Gaillard et al. (2000) demonstrated with fMRI in 8.1- to 13.1-year-olds that tasks with verbal fluency activate the same areas as in adults, but the activation is stronger in children and the right inferior frontal area is active as well. With fMRI Holland et al. (2001) showed in 7- to 18-year-olds, that, correlated with age, the degree of lateralization increased from RH to LH and LH activation became stronger.

To cite Tan, 'It is my firm belief that development from *symmetria* to *rhythmos* is repeated in the development of praxis, speech and language, at least in their earliest stages'. We interpret what Tan wrote to mean the following: it is quite possible that early speech sound signals from the environment (the caretaker) simultaneously with the perception of indicated objects (see the footnote on objects) form neural networks in the homologous secondary temporal-parietal cortices of both hemispheres, connected by an immature callosum. When the child is speaking about these subjects, the very concrete vocabulary of the RH – the earliest ALPS – is strongly multisensorially connoted, including the affect as a 'modus'. This means that neural networks for known objects are connected with ('surrounded by') large networks for sensory features, including the word sound and its prosodic contour and the associated affect belonging to a limbic and network. The early ALPS represent an essence; they have a *rhythmos* of their own.

As soon as the child masters a minimum number of object words and verbs, it will make sentences, a typical LH function. When Tan says that 'The early AMP and the ALP (in the RH) will be transported to the LH', we can assume there is a change in the balance from the right to the left for formal expressive language. Formal language has left the early affects behind it in the RH as well as the multimodal features, which are no longer necessary when words acquire an abstract meaning. Early affects and multimodal features are suppressed, either disconnected in a physical way, and/or forgotten in psychoanalytical terms (infantile amnesia). In some conditions

this suppression/disconnection/amnesia can be reversed: e.g. in the case of aphasia, in psychoanalysis, dreams, physical exhaustion, artistic processes and old age. The shift in balance from early RH ALPs to elaborated language structures is probably not a general and sudden event, as some ALPs are already 'in' the LH, while others are still RH-bound functional networks. This means that the transfer process occurs one ALP after another, and even when completed the LH linguistic structures are still initially unstable, with possible regressions to an infantile status, depending on circumstances.

*The neuro-anatomic metamorphosis of callosal axon configuration.* 'Crossing the midline' is a typical CC function. 'Crossing the midline' is needed in manipulation, but also in axial motor function such as the simple act of walking. The principal function of the CC is: connecting the two hemispheres; there are many more somatosensory callosal fibers for axial/proximal body parts than for the hands and feet. Ideas also cross; in storytelling one speaks of discourse cohesion. The Portuguese neurologist Egas Moniz adopted the term '*liaison des idées*'. Raymond (1906) described '*le manque de liaison des idées*' as one result of CC tumours. These ideas can be either 'motor' or 'mental'.

The connection between AMPs and ALPs and their joint change to the left are not easy to understand nor as yet physically proven. Tan: 'the early AMPs (in the RH) will be "transported" to the LH. We interpret this as a change in activation balance of networks that are located in homologous areas in both hemispheres. Tan described it in this way: 'When speaking develops, some "motor" axons "accompany" the "speech" axons from the RH to the LH. In other words, axons of the ALP in the RH go through the CC to "target" cells in the LH, accompanied there by axons of the AMP'. It is likely that callosal connections between networks in homologous areas begin to activate the left and to inhibit the right side. The ontogenetic process involves callosal function, which is no longer necessary once hemisphere specialization for speech and praxis has been reached. Tan supposes that when this occurs the fiber composition of the CC undergoes a metamorphosis.

The RH AMPs and their transition to the LH may have a facilitating influence on the transition of RH ALPs to the left. AMPs, with the words belonging to them (the word neurons connected to actions are part of the AMP network) promote naming or speaking about the actions the AMPs represent by activating the speech network. The transition of an AMP to the left with its elaboration 'pulls' at the ALP 'to go to the LH' and to elaborate speech as well.

The reverse – in phylogeny and ontogeny – is also possible, but occurs much later: elaborated word use (LH ALPs) has an influence on actions. This influence of words on actions has been beautifully described by Vygotsky (translations 1962, 1977, 1978). He notes that spoken language has an organizing function as regards praxis and that it enables fundamentally new and different behaviour to emerge. In some sense, language penetrates the praxis functions themselves; language (including inner language) and praxis become one integrated system.

*Support for the connection of 'motor' networks to 'speech-language' networks.*

Meltzoff and Moore (see Meltzoff, 1995) showed that neonates imitate elementary hand gestures, facial expressions and vocal gestures and that they observe, imitate, and remember actions in a crossmodal way. They called the mechanism that enables this to occur active intermodal mapping (AIM). After the early phase of imitation, babies will also imitate complex actions and their duration. Performing the action, imitating it and seeing the action performed by others has a common neural correlate in the mirror neuron system (MNS). Hearing an action and seeing a graspable object activates the MNS as well (Rizzolatti et al., 1999). Perceiving an action provokes resonance in the action-producing network (Fadiga et al., 2006).

Infants listen to speech and watch face and the lip movements, a crossmodal matching that is demonstrable at 2 months (Patterson and Werker, 2003). The infant perceives these signals belonging to each other or 'coherently', gestalt-like, theoretically a multimodal RH function. Eye to mouth and hand movements are a coherent communicative gesture, probably understood in one connected cerebral network system for social comprehension. Condon et al. (1974) noted movement synchrony in older children: the child makes nearly invisible eye movements synchronously with its mother's speech and the mother reacts correspondingly towards her child. Austin and Peery (1983) and Kato et al. (1983) found this in newborns as well.

The bonding of the child to the mother, called 'attachment' by John Bowlby (1969, 1973) is promoted by these mechanisms and consolidates from the sixth month on. The attachment, perceptuo-motor interaction and cognitive possibilities offered by object permanence, are the framework for the determinants of the RH stage of speech-language development proposed by Tan. Locke (1993, 1997) called the developmental stage when these determinants are most important, stage 1 of language development.

Fogel and Hannan (1985) published an article on 2- to 3-month-old infants, demonstrating the 'pointing' gesture or index finger extension in 'cooing'. Masataka (1995) demonstrated that index finger extension frequently accompanied speech-like sounds, rarely mere vocalic sounds. In an article on vocalization in one-year-olds, Kent and Bauer (1985) concluded that the appearance of canonical babbling (CB) is not simply a unique phonological phenomenon but instead seems to be closely linked to more generalized rhythmicity of movements. Two papers by Thelen have made important contributions in this field: 'Rhythmical stereotypes in normal human

infants' (1979) and 'Motor aspects of emergent speech: a dynamic approach.' (1991). Thelen's definition of rhythmical action is 'a movement of parts of the body repeated in the same form at least three times at regular short intervals of about a second or less'. Ejiri and Masataka (2001) published a longitudinal study (6- to 11-month-olds) of 4 infants, 2 boys and 2 girls, showing that vocalization frequently co-occurred with rhythmic action (e.g. hand banging) during the pre- CB stage, particularly in the month before infants began to babble, disappearing in the month after CB had begun. These findings suggest the following: 1. Involvement of the RH (rhythm). 2. Involvement of the CC (repetition of a movement involves two kinds of action). 3. Support of 'motor' axons to 'speech language' axons, at least their close connection in some early developmental stages.

Leroi-Gourhan's (1964) palaeontological studies point to the specialisation of mouth and hand function in phylogeny and simultaneous changes in hand and oral anatomy as well as forebrain development, which is ontogenetically repeated in the first years of the human infant. Greenfield (1991) describes the same process in an article entitled 'Language, tools and the brain: The ontogeny and phylogeny of hierarchically organized sequential behaviour', in which she argues that in the phylogeny of primates the earliest words emerged from gesture and action. Both language and gestural activity share the Broca area. Reilly (2002) in a comment on Greenfield, suggests that experience in object manipulation facilitates the learning of both simple and more complex language forms.

We also refer the reader to Kelly et al. (2002). In their paper they present further evidence of the phylogenetic and ontogenetic aspects mentioned above. They cite studies of the MNS, namely that the Broca area (F5 in monkeys) is comprised not only of neurons for oro-facial and tongue movements and hand-motor activity, but also mirror neurons, necessary for understanding gestures and for imitation of manual and oral movements, the beginning of learning. The same relationships are found in the developing infant. The MNS signals only typical actions, one could say 'only actions with a certain essence', or, using Tan's terminology, *rhythmos* or AMPs. Kelly et al. (2002) cite the literature in which it was shown that hand banging predicts canonical babbling, pointing predicts the child's first words and gesture-word combinations predict the first two-word sentences. During early language development, children also appear to benefit from communication distributed across multiple modalities. For abundant information in this area, the reader is referred to this article.

Finally, a hypothesis about how speech evolves from motor function was put forward by MacNeilage (1986). He hypothesized that the LH's manual specialization may have evolved primarily for manual coordination (entailing callosal function), which may be in an analogous mode a precursor to the phonological and syntactic levels of speech. Beginning speech at 6 months (ba-ba-ba) is an alternating motor function, probably involving the callosum. Such labial consonant-vowel sounds in mammals (meow, moo, baa) are phylogenetically very old.

*Lesion studies and subsequent speech-language development.* The clinical picture of postnatal brain damage occurring before the age of approximately 18 months is difficult to distinguish from congenital or perinatal brain damage. Children with very early damage to the RH will, though delayed, speak reasonably well at 5 years of age. Children with severe LH damage before the fifth year will speak, though often with grammatical mistakes (Bates et al., 1992, 1997). Children after early hemispherectomy or hemidecortication of the LH also have these problems. This argues against the idea that in that age period (which Tan called the transitional stage) language is processed entirely by a highly specialised and localised network in the LH. However, this is what happens after that period. After the fifth year, aphasia has more severe sequelae, in accord with the consolidation of Tan's LH stage of language development.

Studies by Bates et al. (1992) suggest that early language comprehension is dependent on the RH. The authors followed children who had had one-sided brain damage before the sixth month. The prognosis was good at the age of 5 to 6 years, although between 1 and 3 years all speech-language milestones and gestures were delayed and expression was much poorer than comprehension. The delays in the second year were not dependent on side, location or the extent of the damage, but between 1.5 and 3 years, or later, children with LH posterior damage were more expressively disturbed both in terms of sentence length and grammatical complexity compared to those who had suffered anterior LH damage. Word production was poorer after left temporal damage, word comprehension after right parietal damage. This is different from adult aphasiology. The adult Wernicke profile was more common in children with RH damage and their low comprehension was a limiting factor for expression. None of the children with damage to the left Wernicke area had a word comprehension disorder. Between 10 and 17 months the RH plays an important role in speech-language acquisition (comprehension) and this is true for gestures as well. The adult Broca profile (poor speech with relatively good comprehension) was present with posterior as well as with anterior damage.

According to Bates et al., the posterior cortex of the LH appears to be relatively important for the production of pronouns and other grammatical function words. Usually children with focal damage showed no correlation between word production and word comprehension, if comprehension was examined within a context. This is what happens in natural situations, at home for example, i.e. the child's comprehension is better than its expression. In such cases the RH is always involved, because there is a relatively high degree of supra-segmental



language aspects. In a context-free test situation, word comprehension and production are indeed correlated and word comprehension depends more on the LH, as has been shown in normals (see below). Recent neuro-imaging work also points to the early role of the RH (Dehaene-Lambertz et al., 2004).

*What speech perception in infancy tells us about hemisphere function.* Newborns recognize and prefer their prenatally heard mother's voice, especially its prosody (DeCasper and Fifer, 1980). This makes it easier for the infant to be in tune with its mother's baby talk (child-directed speech). Newborns can discriminate vowels measured by magnetic brain responses (Kujala et al., 2004): all newborns react to vowels with a steady pitch, and some also react to vowels with a rising pitch, simulating intonation. Some weeks after birth, an infant recognizes its mother's voice and face as different from others' (Mehler et al., 1978 and Molfese et al., 1975). The infant can hear prosodic speech differences as well.

Using auditory evoked responses (AER), Molfese (1972) demonstrated in babies of 1 week to 10 months of age, that for syllables and words there are higher AER amplitudes in the left temporal area, while for non-speech stimuli (musical chords, noise), the AER amplitudes are higher in the right temporal area. Newborns, at 4 days of age, also have a right-ear preference with dichotic listening for consonant-vowel combinations (Bertoncini et al., 1989). Formal word sounds are processed on the left, but these signals only have meaning for the infant if they are expressed in an adequate prosodic way; this is an RH function.

However, Kimura (1963) demonstrated with dichotic listening tests that children only start to develop preference at the age of 4: the right ear (LH) for speech data, the left ear (RH) for environmental sounds and music. She has also proven that girls of 8 are clearly 'lateralized' and hear spoken language preferentially with the LH, 1 to 2 years earlier than boys.

Mills et al. (1994) found in 13- to 17-month-old infants that event-related potentials associated with known words differ from those evoked by unknown words. The differences are seen in both hemispheres, but especially in the RH. At the age of 20 months, the same experiment showed differences predominantly in the LH. Before 20 months a known word (meaning) is processed more by the LH.

The LH temporal lobe is more active than the RH with fMRI in 2- to 3- month-old infants under sedation while they listen to a children's story (with no difference between forward or backward speech); the left angular gyrus and precuneus are more involved in forward speech, whereas the right dorsolateral prefrontal cortex is active only in the awake baby, especially for forward speech (Dehaene-Lambertz et al., 2002, 2006).

Kooijman et al. (2005) have shown electrophysiological evidence of 10-month-old infants' word recognition in continuous speech. In the familiarization stage the effects were seen in both hemispheres. In the test stage the effects were seen in the entire LH. In these experiments sentences for adults were used; they were not natural for these infants nor did they have natural emotional prosody.

In conclusion, most experiments show that formal speech sound perception is processed bilaterally, but preferentially in the LH. Phonetic signals are processed by the LH, while pitch processing is an RH function (Zatorre et al., 1992). Most experiments, however, do not use natural prosodic speech (for comparison), which induces a bias towards the LH.

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