Chapter 19
Dynamic Methodology in Infancy Research

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Infancy research has been a quickly expanding field in recent decades. Since the early 1970s, an increasing body of research demonstrated that the capacities of the newborn baby were far more advanced than previously assumed. New methodologies, such as eye tracking, motor movement tracking, heart rate measurements, EEG measurements, and the like, have been used in experimental settings. Furthermore, video observations have been used to follow, for example, mother-infant interaction, both in natural settings (Trevarthen & Hubley, 1978) and experimental settings, such as in the Strange Situation developed by Ainsworth to measure infant's attachment (Ainsworth, 1982).

While these methodologies and research advances have been helpful in increasing our understanding of infant's complexity, providing a more fine-grained picture of phenomena encountered in infant development, these empirical studies tended to neglect more explicit explorations of their theoretical foundations (Horowitz & Colombo, 1990). In particular, little attention has been given to revealing developmental change processes that contribute to the transformations identified in the infancy literature.

For example, experimental studies to Piaget's findings on object permanence led to the conclusion that the infant displayed a sense for object permanence at earlier ages than predicted by Piaget (Baillargeon, Spelke, & Wasserman, 1985). Accordingly, changes in infants' competence for object permanence over age were attributed to limitations in memory and motor skills, rather than to theoretically driven developmental processes, as originally described by Piaget (1954).

A very important methodological difference between Piaget, on the one hand, and the recent infant research on object permanence, on the other, should be highlighted. Piaget made use of naturalistic observations (referred to by him as "the clinical method"), while many modern infancy researchers use controlled experimental designs such as the habituation paradigm. While Piaget described cognitive development in terms of stages, his main focus was on the *transitions* between those stages.

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In order for him to describe these transitions, he made use of theoretical concepts, such as *organization* and *cognitive structure* to describe the level of functioning of the child, as well as *adaptation* and *equilibration*, to describe the relationship between the child and its environment. Furthermore, he pointed out that adaptation was a two-way process: adaptation of the child to the environment (*accommodation*) and adaptation of the environment to the child (*assimilation*). Notably, this methodological approach used by Piaget, with an explicit theoretical foundation and emphasis on developmental change processes, contrasts with modern infancy research focus on standardized measures such as the habituation paradigm, emphasizing development in terms of clearly-circumscribed variables, such as memory capacity and motor skills.

In an effort to further clarify the importance of redirecting our efforts to better understand developmental change processes, we will discuss potential differences in the basic assumptions about the infant-environment relationship implicit in the prevalent research approach and the alternative we discuss herein.

Infant-Environment Relationship

To the extent that infancy researchers make reference to a theoretical framework—more or less explicitly stated—cognitive science is the preferred paradigm (see, e.g., Spelke & Kinzler, 2007). One of the assumptions of cognitive science that is implicit in much of infancy research is the input–output model of the infant-environment relationship. Without this being explicitly stated, this kind of research makes of the infant a closed system in which the development of inner (physiological or psychological) structures is related to the information input and behaviour output of the organism. From this closed system perspective, information is an a priori input to the system, as in a pattern of sensory data that are processed to a certain structure depending on the (internal) structure of the organism (cf. Valsiner, 1997, p. 24).

Alternatively, there are two related views conceiving the developing organism (e.g., a human infant) as an open system. These two views, the conception of development as *epigenesis* and *dynamic systems approaches*, have in common that they conceptualise the infant-environment relationship as a complex and non-linear *process,* co-emerging in the context of infant development as a whole, including the physical and the social spheres of the developing infant. From this open system perspective, the input-output distinction becomes fruitless as infant and environment complement each other in a dynamic fashion.

The Impact of Cognitive Science on Infancy Research

Within cognitive science, abstract systemic theoretical approaches (e.g., Fodor, 1975) have given way to a focus on the relationship between neurological and cognitive phenomena. This focus implicated a biological developmental perspective (e.g., Elman et al., 1999; Johnson, 1997), in which cognitive development was understood in terms of the development of the brain and other neurological systems. The attention became redirected to the nervous system as the possible central controller of motor and cognitive development. It was as though the shift was moved, away from the environment as an "external" influence, to maturational forces.

Although influenced by cognitive science, infancy researchers continued to not adopt the more systemic proposals emerging in cognitive neuroscience, such as connectionism and neural networks. Thus, most infancy research remained focused on revealing higher competence than previously assumed, pointing out the relationship between behaviour and specific neurological structures. Furthermore, such emphasis on describing behaviour in light of neuro-physiological processes is still heavily influenced by the input-output model of the infant-environment relationship described earlier. It is our contention that in such input–output models the infant is conceived as a closed system, and there is no mutuality in the relationship between organism and environment. Thus the structural aspects of the organism are described independently of the environment, in which it lives.

Development as an Open System: Infant-Environment Mutuality

A mutual relationship, on the other hand, implies an ever-ongoing exchange between the infant and the environment, in such a way that changes in the infant as a consequence of environmental influences also implies changes in the environment in light of the (changed) activities of the infant. This mutuality occurs in open systems where the boundaries between input–output become blurrier, since the changes in the infant-environment relationship co-emerge.

An early description of such a relationship is offered by Piaget (e.g., Piaget, 1963) with his idea of adaptation as a dynamic relationship between assimilation and accommodation, as described above. In the case of Piaget, the relationship between assimilation and accommodation was internal to the organism. For example, a child at the same time assimilates impressions and things from the external world to its internal structures and accommodates these structures to the changing external circumstances. While Piaget defined the infant relationship to the environment in a reciprocal and dynamic manner, his emphasis remained on conceptualising adaptation as internal to the organism. In other words, the infant is beginning to be viewed as an open system but the internal–external distinction remains implicit. Later, Valsiner (1997, p. 23ff.) offers a formal description of the open system's relationship between organism and environment, stating that biological, as well as psychological and social systems, are intrinsically open systems.

With reference to Bertalanffy (1950), Valsiner describes closed systems as systems that "do not depend for their existence on exchange relationships with their environment". Another way of explaining the nature of a closed system is to say that it is *designed,* that is, for example, that it is based on a blueprint or is pre-programmed.

An important consequence in the functioning of a closed system is that if the structure of the system changed, the system would break down, similar to an engine that stops working if any of its parts does not function according to the engine's blueprint. However sophisticated, a computer is a closed system, that is, it is designed, both to hardware and to software, and it needs precise instructions to work. It may learn, that is, incorporate new information into its system, and thus change its way of functioning. However, this requires a very precise set of instructions, that anticipates each and every possible future learning situation and thus also close monitoring, while interacting with the real world. The ultimate consequence is that a closed system needs to be *context independent* and solutions are not emergent; instead, a closed system needs to incorporate representations of each and every possible contextual possibility into the system, as well as representations of the right action for each contextual possibility, such that the relationship between specific input to and specific output from the system always remains the same. Learning would imply that specific changes in input would lead to predefined changes in output.

It is obvious that infancy researchers inspired by cognitive science resist the idea that this closed system model as portrayed above is a proper model for infant functioning and development. However, as pointed out by Costall and Leudar (2004), while showing that infants proved to solve tasks considered as cognitive much earlier than reported by Piaget, provided that the context was appropriate, infancy cognitive researchers did not study their participants in context, but rather designed settings where context was either eliminated or highly controlled, using standardized measures such as an habituation paradigm. In most cases, these highly specific and isolated "contextual factors" were defined and operationalized as independent variables and the go was to identify clear input (independent variable) and output (dependent variable) relationships without taking into account the potential influence of other contextual factors, not anticipated. With such a clear distinction between input, infant, and output, as well as the ambition to control or eliminate context, this kind of research could be described as representing a closed systems' view, rather than an open systems' view of the relationship between the infant and its environment, as described here above.

Furthermore, such closed systems' approaches in methodology was not easily integrated with theoretical notions of a complex and highly competent infant (e.g., as described in Stone, Smith, & Murphy, 1973). Therefore, rather than trying to corroborate their cognitive theories by their empirical findings, many infancy researchers addressed data-driven issues focused on limited and well defined infant performances such as imitation, reaching for an object, or looking time to an unexpected—as compared to an expected—event, offering an unprecedented increase in knowledge about infant capabilities. The theoretical conclusions implicit in these studies were, to a considerable extent, in terms of nativism and maturation, suggesting inborn capacities triggered and refined by environmental stimulation (see Costall & Leudar, 2004).

Open systems, on the other hand, imply that development is context dependent and emergent. This means that open systems are "dependent on exchange relationships with their environment and their structural organization is maintained, or enhanced, by these relationships" (Valsiner, 1997, p. 23ff.). We will elaborate later on the theoretical and methodological implications of considering the human infant as an open system. Before that, in order to better understand the crucial difference between closed and open systems, let us turn to artificial intelligence, having the ambition to design machines working in the same way human cognition does. In cognitive psychology's (including infancy research) dedication to the experimental method, the basic three-part model for research is stimulus (independent variable)—intervening variable (e.g., cognition)—response (Costall & Leudar, 2004). Stimuli and responses are observable and measured. The intervening variables, on the other hand, are non-observable and inferred from the stimulus-response relationship. Thus, there is a clear distinction between the central system (inferred and described in terms of intervening variables) and the interface with the environment, that is, stimuli and responses.

Similarly, in computer science, this distinction is fundamental and is expressed as the difference between the central system (an information processing device) and peripheral systems (such as keyboards and screens) that implement the central system's relationship with the environment. Instead of a model for artificial intelligence based on the distinction between central and peripheral systems (which have all the constraints of closed systems), Brooks (1991) argues that an intelligent system should be based on very limited direct perception-action couplings with a minimum of processing capacity that are capable of doing a very simple job in any possible condition. Each such system, in Valsiner's terminology, would in fact be a context independent *closed* system. However, these systems lack any elaborate central representations of external world and of the task to be performed (to the difference from the closed systems described here above). Such sub-systems in an artificial intelligent system are not defined by their function (e.g., knowledge representation, planning, language, vision, smell, etc.) but by their *activity* (e.g., sensing open space-move on/sensing obstacle-stop). *Layers* of such simple subsystems, where there is no intermediate between input and output, may in an incremental way constitute a system that may freely move around in a natural environment, handling new, non-planned situations without these situations being represented in the system. While the component simple subsystems are context independent (they react in the same way, irrespective of the situation), the layered total system (a robot) will react according to the context it finds itself in (e.g., in the simplest possible case, the robot will move around while avoiding obstacles and exploring open spaces). The way different layers interact must be specified, such that the system is in that sense designed. However, these specifications are not linked to external circumstances or specific actions of the robot, they concern only how the different layers are connected (wired) to each other. Thus, the robot as a whole will function as an open system, as its actions are context *dependent,* that is, what it does depend on the situation it finds itself in. Modern robotics took quite a different, more successful turn, as the research strategy changed from, in our terms, a closed systems' view to an open systems' view on the relationship between the robot and its environment. Rodney Brooks at MIT, cited here above, played a crucial role for this change in strategy. It has been followed by very interesting comparisons between "developmental robotics" and infant development (e.g., Smith & Breazeal, 2007) featuring descriptions of the relationship between infants—as well as robots—and its environment that correspond well to Valsiner's open systems' view on this relationship.

Viewing the organism-environment relationship as an ongoing mutual relationship, where Heraclitean change is ubiquitous (for a synopsis on the Greek philosopher Heracleitos, see Graham, 2006), calls for theoretical and methodological approaches that capture and account for the dynamic character of such relationship. We now move on to presenting the kinds of approaches to development that imply a view of the organism as an open system: the view on development as epigenesis and dynamic systems approaches (DSA). The epigenetic view on development (e.g., Gottlieb, 2003) has not had any direct influence on infant research. However, it sets forth general principles of development that, in our view, nicely complement the DSA explication of the change processes that underlie infant development.

Open Systems' View on Development

Epigenesis: A Basic Principle for Development

In biology, *epigenesis* is a well-known and generally accepted concept. It refers to the process through which the shape of the organism and its different parts/organs develop, taking into account that this shape is not pre-formed at conception, but emerges out of a single cell (the fertilized egg or seed) through a process of differentiation and integration, *morphogenesis* in biology, cf. the *orthogenetic principle* (Werner, 1957) in psychology.

However, in an early understanding of epigenesis, the development of the organism was considered as predetermined (Gottlieb, 2003). This view was supported by the discovery of DNA, considered as a kind of blueprint for the organism, or a programme to be implemented in the epigenesis of the organism. This view was widely adopted, in spite of findings of experimental embryology that contradicted this assumption of *predeterminism*, showing that the implementation of the gene information was highly influenced by environmental factors.

Gottlieb (e.g., 2003) was a pioneer in showing that the blueprint view was not fruitful, both by careful experimentation carried out by himself and referring to earlier research. Altogether, Gottlieb shows that the expression of genes is dependent on timing as well as situational and environmental circumstances. For example, Gottlieb (2003, p. 9) referred to one of the earliest experiments in experimental embryology (carried out by Hans Speman in 1918) where a transplantation of head (potential brain) tissue from an embryo early in the development (in the blastulad stage) to the back of another embryo of the same species (newt) resulted in the tissue developing according to its new environment. In contrast, the same transplantation later in development (end of the gastrulation stage) led the brain tissue to develop into a third eye on the back of the animal. Similarly, embryonic stem cell research demonstrates the plasticity of cells and how their specificity and function emerge in light of its location in relation to its neighboring cells. Another well-known example of this dynamic sensitivity of the organism in relation to its environment is prenatal sexual differentiation. While the 23rd pair of chromosome is often viewed as determining one's anatomical sex, environmental influences such as prenatal exposure to sex hormones can transform that process, resulting, for instance, in a chromosomical female (i.e., xx) who is anatomically male. Thus developmental outcome, even at the cell level, depends both on timing and the surround. As highlighted by Gottlieb: "Although we do not know what actually causes cells to differentiate appropriately according to their surround, we do know that it is the cell's interaction with its surround, including other cells in that same area, that causes the cell to differentiate appropriately" (2003, p. 9).

Recent research on the notion of epigenome (also known as "ghost genes") hints at an understanding of a complex, non-linear view of genes-environment relationship. This line of research argues that "(…) complex human conditions (such as obesity and cancer) can arise from environmental alteration of the epigenome" (Luedi et al., 2007, p. 1728). To put it simply, the epigenome works as a form of parallel genome by instructing genes in an organism's genotype to be activated or not. Alterations in the epigenome (and what, when and where genes get activated) result from complex interactions with environmental conditions, thereby contributing to varied phenotypes even in identical twins raised in similar environments (Dolinoy, Huang, & Jirtle, 2007). The research on the epigenome thus further substantiates the argument for the integration of levels in the systems view of psychobiological development proposed by Gottlieb, from genes to culture.

The epigenome seems to be a worthy candidate for assuring gene regulation according to the surroundings of the single cell. This regulation, in turn, is mutual and is better understood when we take the time dimension into perspective. In other words, the gene expression will result in new cells that, over time, will change the cells surroundings, in turn, possibly altering the epigenome and the further expression of the genome. This is the central implication of epigenesis that we want to stress here: Each future state of the organism depends on its present and earlier states, including the present environment. These recent findings about the epigenome and cell plasticity nicely substantiate the open system's character of biological organizations. There is a continuous reciprocity between the organism and its surround, such that the organism continuously ingests nutrition and sensory impressions (by no means passive processes, as the input–output model suggests) while at the same time the organism acts on the environment, thus changing it.

As discussed above, the same mutuality works at the cellular level. Knowledge about the functioning of the epigenome gives a precise, biochemical description of the nature of this reciprocity. It is also important to point out that the sensitivity of the epigenome to history and the environment may lead it to give instructions to the genome that are not necessarily beneficiary to the organism. For example, the genome contains potentials for developing cancer cells. Normally, the epigenome "silences" such genes, preventing them to be expressed. However, under certain (environmental) circumstances that is not the case, and cancer may develop. As if that were not enough, the epigenome also becomes muddled with age, becoming more prone to maladaptive influences on the expression of the genes. For the purpose of this chapter, it suffices to know that the epigenome seems to be nowhere and everywhere, it is specific to different types of cells, it changes over time and according to its immediate and distant environment (for example, chemical compounds ingested through food—the present major area of research on the epigenome, as a way of understanding the development of cancers, see e.g., Dolinoy et al., 2007).

This entire discussion is part of *epigenesis*, a strongly growing area of research in microbiology. We have here tried to point out two ideas: First, the interconnectedness of levels of analysis in epigenesis. To take an extreme example, through the different levels of organismic functioning, culture may have an impact on epigenesis on a cellular level, and vice versa. Second, epigenesis has an historical dimension: What will happen to you in your immediate future depends on where you are now, which, in turn, depends on the succession of events and circumstances that make up your past. As a third point, we should not forget the original idea that epigenesis implies development from simpler to more complex structures.

This main premise is true for phylogenesis, the development of species, as well as for ontogenesis, the development of an individual organism. Life on earth started with single cells, some 3.5 billion years ago. Human cognition—in any understanding of these words that distinguish us from the great apes—have existed in approximately 2.5 million years (Brooks, 1991). Single cells are open systems, in continuous interaction with its environment. The simple tasks that have been solved by this interaction are survival and reproduction. Selection pressure has lead to the evolution of more and more complex organisms, where survival-promoting specializations emerged, out of the condition under which organisms had to live. It is important to notice here the difference between an epigenetic view, as proposed by Gottlieb, and the common evolutionary view, where random diversity is the sole mechanism promoting “the survival of the fittest”.

With these intricate relations in the structure of the organism, at different levels of analysis, and between the organism and its environment, it is difficult to conceive development to be regulated by linear causality. But if not, how can change processes, that undeniably take place, be described? To answer this question we turn to dynamic systems approaches (DSA). Some modern infancy researchers (e.g., Fogel, 1993; Lewis, 1995) use dynamic systems principles to understand infant development as the development of a neurological organism in relational contexts. A similar movement is observed in neuroscience. Of particular note, the concept of neuroplasticity emphasizes the dynamic relationship between brain development (at all ages) and its relation to the surrounding (Doidge, 2007).

Theoretical Foundations of Dynamic Systems Approaches

More than any other theoretical approach, the DSA has provided a framework for conceptualizing the organism as a continuously active open system. In their well-known to the public book, Prigogine and Stengers (1984) proposed principles to explain the emergent structure and behaviour of non-organic matter as well as biological and social systems; and such principles are at the basis of DSA today. According to Prigogine and Stengers, organizational changes in open systems take place whenever, and wherever, certain conditions prevail in a delimited structure and its environment without anything else being fed into the system than unspecific energy. That implies that what is fed into the system does not contain specific instructions as to *what* changes should take place. Consequently, what determines the structure and behaviour of a system are particular *relational conditions* of the system and the environment, under the influence of the unspecific energy fed into the system. Organization thus emerges in the system when certain conditions prevail, and in that sense the system self-organizes. When these ideas are transposed to psychology a qualification is in place of what will sustain and enhance the structure of the system. Information will play the same role as energy. Although structured, information is not specific to the system, but constitutes a *resource* for the system, in the same way as energy (van Geert, 2003).

Thus information does not impose structure on the system from the outside. It contains no instruction whatsoever on how the system should be organized. Organization rather emerges within the system under the influence of energy and information as resources for the system. Take, for instance, a social system where a mother provides an infant with a particular toy, a rattle, demonstrating how it can be used, by shaking it. The mother is not necessarily organizing the rattle shaking behaviour in the infant (≈ teaching the child how to make the rattle noise). What she does instead is to set the conditions under which the infant may discover the pleasure of rattle shaking. When the neurological status of the infant is appropriate and the infant is well fed and rested (energy), for instance, the *information* provided by the mother on rattle shaking (i.e., the infant sees and hears what the mother is doing) create an opportunity for the child to organize its behaviour into rattle shaking, which, most likely, will occur slightly different from the way the mother originally presented it.

Now, if we look at the same example from the assumption of the child as a closed system, the description will take a radically different turn. When the mother is demonstrating the rattle for the infant, she is literally *teaching* the infant how to make the rattle noise, that is, *she is organizing* the rattle shaking behaviour of the infant. Later on, when the infant develops a representation of a rattle, he or she will recognize a certain object as a rattle and use it as a rattle the way his/her mother taught him/her. Thus, the development of a structure in the individual is directly linked to the structure of the external world. In this sense, one could say that the environment, for example, the infant's mother, designs his or her cognition (cf. van Geert's, 2003, p. 648ff., discussion on design vs self-organization).

The closed system description of the example above resembles the way a computer works, which is often utilized by cognitive science as a viable metaphor to describe the organism-environment relationship. A computer needs both energy and information to work but is designed, a priori, by an engineer. Electric energy supports the system such that the binary instructions may function by switching currents on and off. It provides no structure to the system. However, information provides the system with structure in the form of computer programs and data input. Similarly, within this perspective, the organism is "designed" based on its internal, inborn (hardwired) information stored in its chromosomes while external information is being fed into the organism from the environment through its sensory systems. In these cases (computer and organism, viewed as closed systems), change occurs within the constraints of a previously circumscribed system: in the computer, its hardware; and in an organism, its genotype.

The implications of these different views of a child as a closed or an open system are deep and obvious. From an educational point of view, it is the difference between the teacher feeding knowledge into the learner, on the one hand, or being a provider of optimal conditions for a self-learning process on the other. Modern pedagogy likes to conceive of the teacher as a resource. Dynamic systems approaches provide an excellent theoretical foundation for such a view.

Open Systems and Autopoesis

From a theoretical point of view, we may understand the difference between an organism as a closed or an open system in terms of organization from outside, or from inside, that is, self-organization. A car, for example, is organized from outside, it is designed by a team of engineers, and other designers, to work according to a preconceived plan. This plan might be environment-friendly, the car being equipped with solar panels that convert energy from the sun to electricity, which can run the engine. In order for the car to work as planned, every detail that is involved in the running of the engine must function according to the preconceived plan. In case of failure of one detail, the engine stops running. It is a classical example of a closed system.

Plants, on the other hand, are open systems in that they are organized in such way that solar energy directly "makes sense" to them: it allows the plant to extract carbon dioxide from the air, separate carbon from the oxygen and use this carbon in the construction of itself (cf. the concept of *autopoesis*, Maturana & Varela, 1987). Notice that plants have not been pre-designed to perform this process, not by God, neither by the genes. Rather, the process emerged through a series of conditions that were ideal for carbon, that is, organic compounds, oxygen, water, minerals, whatever is needed for these compounds to *organize themselves* into what becomes the plant. In a simplified manner, this process *emerged* as follows: there were oxygen, carbon, and other matters such as water, which made life possible. When a certain number of these components were in place on earth, under the energy radiated from the sun, ideal conditions were in place for some of these matters to *organize themselves into living systems.* This means that different kinds of matter, when available in a certain combination under particular conditions, were able to organize themselves into a unified system, called an organism. This is the deep meaning of the famous phrase "order out of chaos", coined by Prigogine and Stengers (1984) in their best seller book.

Thus, living systems *self-organize* under particular initial conditions and a particular kind of energy supply (Kellert, 1993). However, what is peculiar to living systems is that they also use energy to sustain continuous exchange processes with their environment, thereby producing "waste" products. These "waste" products might, in turn, benefit other living systems that may have self-organized as a result of different combinations of matter compounds, under similar (or different) circumstances. A good illustration of this interconnection is animals consuming oxygen discarded by plants (as well as, of course, parts of plants) and plants consuming excrements discarded by animals. Therefore, different organisms self-organize into ecological systems, functioning at more complex levels than the individual organism and the single species alone. These self-organized ecologies in turn create new potential for the system (in this case, the species) to self-organize again into even higher kinds of systems.

The principle of self-organization thus shifted our view of nature (Kellert, 1993; Kauffman, 1993) and the evolution of species. It is not only the survival of the fittest, not even the fittest for a specific ecology. Evolution emerges through self-organizing processes of existing ecological and interconnected systems, where the evolution of a particular species is intricately related to the entire surrounding ecology of this species. There is a constant give and take among the different organisms, both within a species and between species. This self-organizing nature makes individual organisms, as well as different species, open systems, where the give and take is a prerequisite for their sustainability.

To recapitulate, this dynamic systems view of life on earth is based on the concept of self-organization. Self-organization is not unique to life. Non-organic matter also self-organizes, such as the pattern formed by iron filings on a sheet of paper under the influence of a magnet underneath the paper. Self-organization is a fundamental principle of nature and it can be contrasted to organization by design (van Geert, 2003, p. 659f.). In the organization by design model, the structure of organisms is explained with reference to genetic (structured) information, information in the environment (learning), or a combination of the two. In contrast, under the perspective of the principle of self-organization, the discussion on the relative influence of genes and environment becomes fruitless. As we discussed above, living organisms (i.e., open systems) emerge and develop under specific conditions, both of the environment and of the system itself. Without DNA, there would be no organism. Without an appropriate environment, there would be no organism either. However, neither do genes, nor do environmental conditions provide the organism with structure. What genes and the environment do is to provide conditions/opportunities under which structures (or patterned organizations) may emerge through self-organization.

But what do these excursions into epigenetics and dynamic systems have to do with methodology for studying infant development? We would say: “Everything!” as it sets the basic conditions for a methodology that captures and accounts for the change processes involved in infant development.

An Epigenetic View and Dynamic Systems Approaches in Infant Research

There is no explicit reference to epigenesis in research on infant psychological development. While being a central concept in biology, it is evident that an epigenetic view has much to offer in the understanding of infant development, as well as in guidance on the choice of methodology. Development takes place over time, and in order to study development from that perspective we need concepts that handle the time dimension. We have here tried to point to the advantages of an epigenetic view in this respect, notably providing a model for handling the historical dimension of development, as well as the relationship between past, present, and future. The epigenetic view also handles the relationship between different levels of analysis, from the genome to culture, and we are indebted to Gottfried Gottlieb for making this clear to us. A combination of these two contributions of an epigenetic view, the time dimension and levels of analysis, allows us to define different time scales for development, the differences between and the relationships with which are important to handle in order to define a methodology adequate for the research question at hand.

In our approach, described and exemplified below, we make the distinction between three levels, on the one hand microgenesis, consisting of two time scales, real time in the mother-infant interaction during a particular session and historical time, accounting for the longitudinal series of sessions under study. (We contend as a fundamental methodological assumption that developmental research *must* be longitudinal, that is, in order to study change processes.) Microgenesis, in turn, should be put into the context of ontogenesis, the development of the individual as such. Beyond that, culture-genesis (Valsiner, 1997) and—ultimately—phylogenesis and the development of our planet are time scales that are linked to what happens with the epigenome at the time scale of cellular development. For our purpose, a methodology is chosen on the mirogenetic time scale, as it has the greatest potential to account for ontogenesis in a context of social relations, which we consider as fundamental to our understanding of the development of the human infant.

DSA, on the other hand, has since long challenged the closed system's view of infant development described above. One may discern two kinds of approaches in infant research that make reference to Dynamic Systems Approaches: *mathematical* and *metaphorical*. The former approaches conceptualise development in mathematical terms, or at least aims at such a conceptualization, and thus are referred herein to as mathematical dynamic systems approaches. They have strong links to the natural sciences and, while recognizing the complexity of the system, try to identify variables (control parameters) that regulate changes in the system. The pioneering work of Esther Thelen and her collaborators, focusing on infant motor development, is the most typical proponent of this trend (see Thelen & Smith, 1994, for a comprehensive overview). This mathematical approach has also been used to study cognitive development, language development, and the like (Smith, Thelen, Titzer, & McLin, 1999). The goal is to predict, and possibly control, the development of the system by potentially redirecting the self-organization of the system towards a preferred direction. Within these approaches, two methodologies are often utilized: differential equations and/or computer simulations (Luenberger, 1979; van Geert, 2003), as illustrated in the area of "developmental robotics" (Smith & Breazeal, 2007).

The main focus of research from this approach has been Thelen and collaborators' studies on infant motor development, in particular walking (e.g., Thelen, Kelso, & Fogel, 1987). In the cognitive field, the most well-know example (which is enlightening in regard to our previous discussion of the distinction between an open system's view, as opposed to a closed system's view) is based on the work of Piaget (1963) on the fourth sensorimotor substage. Specifically, Piaget observed that infants between 8 and 12 months understood that an object continues to exist even when out of sight (his concept of object permanence), however, this understanding of object permanence being dependent on the place where the object used to be. He noted that when repeatedly hiding a toy under the same pillow out of the two available, the child will consistently look under the "right" pillow where the object is repeatedly hidden. However, if you then hide the toy under the other pillow while the child is watching you hiding it, the child will nevertheless continue to look under the pillow where the toy used to be hidden. This observation has been named "the A-not-B error".

Let us compare different explanations of this phenomenon. Piaget's own explanation was that a complete object concept at that stage is not yet fully integrated in the child's cognitive structure. Therefore, the toy will be dependent on the external context in which it is conceived to be, also when the child does not have direct visual contact with it. A behaviourist explanation would be in terms of reinforcement by earlier successful retrievals of the toy. The cognitive explanation would be in terms of an internal mental image that is not yet complete, and which prevents the child to remember the object as such (on object permanence, cf. reference to Baillargeon, et al., 1985, here above, p. 431). The DSA explanation offered by Thelen's team (e.g., Smith, et al., 1999) is that the issue is not about an object concept or representation, but about actions in context. Repeated retrievals of the toy under the first (A) pillow has provided the conditions for the self-organization of the infant's behaviour into a strong habit for action (an attractor state, in DSA terminology) where looking and reaching are strongly integrated. The second pillow simply is not a part of this behavioural attractor state, that is, the child does not pay attention to it. If you were, right before reaching for the toy to hide it, drawing the child's attention to the second pillow, it will be taken into account as a possible hiding place for the toy. According to Thelen, the unaided inclusion of attention to the second pillow into a more complete system will require a more advanced mobility (walking around), where attention to different objects in the surround cannot be so tightly coupled with any actual action. (For a detailed, and at the same time succinct account of the DSA explanation of the A-not-B error, see van Geert, 2003, p. 661f.).

While the theoretical explanation of these results distinguishes the studies of Thelen's team, they follow about the same experimental design as studies among other modern infancy researchers, notably doing controlled experiments without considering the social-cultural contexts of infants' activities (see Spencer, Smith, & Thelen, 2001). The theoretical explanation takes the child's earlier and general experiences into account, as well as the real time processes in the experimental situation. However, as the conclusions are based on out of context group data, the underlying assumption suggests that the same processes are taking place in any child placed in the same situation. In DSA terminology, the aim of the studies is to identify relevant *control parameters* that explain why the child behaves in one or the other way, in the case of the A-not-B error, self locomotion, as described above (Thelen & Smith, 1994, p. 304).

Another dynamic systems approach, referred herein to as metaphorical, does not aim to identify key control parameters of complex developmental systems. Instead, using qualitative and life history methodological traditions, the goal is to describe the subtle steps in the developmental process. Within this metaphorical approach, describing is explaining because it is through detailed descriptions of the dynamics of self-organization that one explains the functioning of the system. The purpose of this approach is thus different from that of mathematical inclination. There is no attempt at describing a mechanism at work, but rather at describing the processes involved in the evolution of the system. In other words, developmental—and historical—processes are revealed through detailed descriptions over time of, for example, mother-infant interaction in individual dyads.

The Relational-Historical Approach

In infancy research, one of the most notable sources of inspiration for this metaphorical approach is the work of Fogel and his collaborators, referred by them to as the relational-historical approach (e.g., Fogel, 1993; Fogel & Garvey, 2007; Fogel, Garvey, Hsu, & West-Stroming, 2006; Fogel & Lyra, 1997). In addition to its emphasis on descriptive research, an important contribution of the relational-historical approach is its focus on the relationships the infant has with its environment, physical and social.

The concept of *co-regulation* is crucial in this approach as it implicates that developmental changes co-emerge as infants engage in relational processes with their primary caregivers. In Fogel and Garvey's (2007) words:

> co-regulated communication occurs (…) when partners are open to mutual influence, and when the resulting process creates new information, information that was not entirely available to the participants prior to this instance of their joint engagement (p. 252).

The relational-historical approach is also comprehensive in that it covers infant development from an *historical* perspective. Each relationship is deployed in time: in real time, through the actions that embody the relationship at a given moment, and in historical time, through the patterned routines relationally co-created through these real time exchanges. For example, in a diaper changing setting, parent and infant collaborate, more or less smoothly, through bodily movements. Specifically, as the dirty diaper is removed, followed by the parent's action of cleaning up the infant before putting a new diaper on, the parent may talk to the infant while eye contact and exchange of facial expressions are observed. All of these detailed actions constitute a complex emotional atmosphere that emerges during diaper changing in real time. Parent and infant may then co-create specific diaper change routines that tend to recur over time as previous diaper change experiences influence the ongoing parent–infant transactions. In this sense, relationships are deployed not only in real time, but also in historical time. In other words, the emergence of any given relational routine in real time is, in part, dependent upon its historical "roots" previously and continuously co-created by the relational partners. Through these dynamics, involving real time encounters and historical time changes, each moment can be conceived of as requiring an historical understanding in which these time scales are taken into consideration (for a more detailed account on time-scales, see Fogel & Lyra, 1997; Lewis, 1995; Lyra, 2000; Thelen & Ulrich, 1991). Therefore, strongly influenced by the principle of self-organization, the relational-historical approach argues that descriptions of the details of humans' day-to-day experiences over time are at the core of a developmental analysis (Garvey & Fogel, 2008).

The Concept of Frame

In an effort to develop an heuristic tool to capture this dynamic, time-sensitive nature of relationships, Fogel (1993) borrows the concept of *frame* from Goffman (1974). Frames are useful because they allow the observer to identify structural, recurring aspects of relational, shared experiences. Frames have been defined as "segments of co-action that have a coherent theme, that take place in a specific location, and that involve particular forms of mutual co-orientation between participants" (Fogel et al., 1997, p. 11). In other words, as participants select some actions while communicating with one another, they co-define the format of their communication, framing it in a particular way. Different body positions are observed, the use of certain tools, the performance of specific gestures, and so on, to compose and define each particular form of communication routine (or frame).

The concepts of *co-regulation* and *frames* thus allow us to shift our attention away from changes in the infant and caregiver while inter-acting to focusing on historical and relational changes in infant development. Two examples of our research studies (on infant emotions and infant intentionality) are provided, focusing on the methodological implications of the relational-historical approach with an emphasis on the principle of self-organization.

The Relational-Historical Approach and Infant Emotions

Garvey's developmental investigation is grounded on the notion that emotions and communication constitute a dynamic developmental system (e.g., Garvey & Fogel, 2008). Emotions are viewed as relational experiences lived in bodies that co-regulate their movements with the movements of others. Inspired by dynamic systems perspective and the relational-historical approach, emotions are examined as self-organizing through communication processes. In other words, emotions emerge as the various constituents of communication (such as facial actions, gaze, body movements, vocalizations, and gestures) coalesce into coherent patterns that support infants' meaningful relationships with others. For a more detailed discussion of emotions from a relational-historical approach, see Garvey and Fogel (2007, 2008).

As proposed by the relational-historical approach, this perspective of emotions calls for a close examination of real-time and historical-time changes across key developmental transitions (e.g., Fogel et al., 2006; Garvey & Fogel, 2007, 2008). In Garvey's work, the key developmental transition emphasized is the well-reported transition from a primary focus on direct, face-to-face communication between mother and infant to a primary focus on object communication, observed in the first 7 months of an infant's life. This developmental analysis is accomplished using longitudinal video-recordings of mother-infant dyads, visiting a laboratory playroom three times a week for a period of 4 months, starting when the infant was 10-weeks-old. Systematic observation of free-flowing communication between an infant and his mother, multiple patterns of emotion were identified in the ways the partners of the dyad related to one another. These emotions, self-organized as frames, were co-created by the infant (whose pseudo-name is Nathan) and his mother, pseudo-named Patricia.

In the first five visits, frames involving the direct connection between Nathan and his mother, without the consistent use of objects (referred to as *social playful frames*), are observed: these frames range from playful moments involving positive emotions, composed of large smiles, vocalizations, and tactile games, to more mellow moments between Nathan and his mother involving mutual gazing, subtle smiles, and soft touches (as shown below).

In these frames, both mother and infant are predominantly co-oriented to one another, continually co-regulating their movements with respect to one another. Over time, as new information is spontaneously introduced by the mother, for instance, the infant starts staring at a toy within his sight or the mother starts playing peek-a-boo with her infant using a toy, the potential for a reorganization of the system emerges. This introduction of novelty and potential for systemic reorganization is observed between sessions 5 and 9, when Nathan and his mother begin to more consistently introduce novel activities to their existing frames. More specifically, with the inclusion of toys into their social playful frames, new emotion patterns begin to be formed (such as an increasingly more focused interest on toys) while familiar routines are also slightly modified and incorporated in the flow of the dyad's communication (referred to as *social-object playful frames*—shown below).

These newly emergent frames predominantly observed between sessions 5 and 9 thus include playful moments but also toys as part of the new dyadic patterns of emotion exchanges involving smiles, vocalizations, and mutual/alternate gazing between Nathan and Patricia. By integrating these familiar routines (i.e., social playful frames) with the novel introduction of toys, Nathan and Patricia gradually and spontaneously co-create conditions for the emergence of social-object playful frames as well as the increasing complexity in the infant's emotional repertoire.

Over time, both of these playful frames—with or without toys—appear to become less predominant while another frame emerges. Specifically, between visits 10 and 20, a phase shift in the dyad's playful routines seems to occur: Nathan begins to consistently engage in a form of absorbed toy interest by persistently exploring his hands and/or toys through mouthing, while the mother quietly observes her infant, often holding a toy in front of the infant to observe/explore or providing postural support to his explorations. This frame, which becomes gradually more predominant in the landscape of this dyad's communication system, is referred here to as *interest in toys frame* due to the dyad's clear and more serious/concentrated co-orientation towards the toy (as shown below).

These excerpts from our microgenetic analysis attempt to illustrate how the dyad partners gradually shifts their focus from direct-playful frames to frames characterized by the infant's concentrated interest in toys while the mother quietly observes him. Most importantly, the distinct emotions, that add the characteristic quality of each frame, self-organize as part of the emergence of the frames themselves. Emotions are not examined as internal states expressed outward as a result of environmental influences, often deployed by the mother. Instead, through communication routines, elements of positive emotions self-organize into recurring patterns, that is, *frames*, co-created by the mother and her infant. In other words, the infant gradually develops distinct emotion patterns through his relational moments co-created with his primary caregivers as they navigate across key developmental transitions. Thus, infant emotions develop over time as part of this communication system, both viewed as part of an open system susceptible to changes.

The Relational-Historical Approach and Infant Intentionality

Vedeler (e.g., 1991) studies the development of infant intentionality from the perspective of conceiving infant intentionality as behavioural object directedness, rather than as mindful goal directedness, the commonplace definition in psychology. The issue addressed is the impact of the development of a caretaker-infant relationship for the development of infant intentionality. Trevarthen (1979) has described the development of infant intentionality in three stages; the first features a purely social intentionality ("primary intersubjectivity"), the second a purely thing oriented intentionality ("epoch of games"). In the third stage, "secondary intersubjectivity", the child arrives at combining social and thing oriented intentions, thus laying a foundation for language and cognition (Trevarthen & Hubley, 1978). Trevarthen assumes that an innate capacity for combining social and thing-oriented intentions matures in the infant. As an alternative explanation, Vedeler's research proposes that the third stage in Trevarthen's description emerges as a consequence of the self-organization of the caretaker-infant relationship. Thus, before becoming a mental-cognitive ability of the infant, secondary intersubjectivity is manifested in the relationship as a re-organization of the concrete co-actions of caretaker and infant, for example, playing with a toy.

In order to capture the process of change leading to the dyad's reorganization of its co-regulation to cover secondary intersubjectivity, Vedeler's research program looks for precursors of secondary intersubjectivity in the caretaker-infant interaction from 5 to 10 months. The methodology is based on Fogel et al.'s (2006) elaboration of microgenetic design within the relational-historical approach described above. The aim is to show how the constituents of secondary intersubjectivity are built up in concrete interaction that is constrained by the history of a dyad's relationship and the actual situation, including social and physical properties of, for example, a toy.

For that purpose, weekly video recordings of mother-infant interaction, between infants' 5th and 10th month of life, involving the same toys, are observed and described in terms of narratives of each frame of interest. Frames are circumscribed in Vedeler's study by the particular toy the dyad is utilizing. As the same set of toys is available at each recording session, the dyad frequently plays with the same toys over many of the weeks covered by the study. Thus, we are able to follow the development of the particular frame linked to a particular toy. Specifically, microgenetic changes in the way mother and child are playing with the toy, based on established routines linked to the particular properties of the toy, its socio-cultural significance (canalized through earlier experiences of the mother) and co-regulation of the situational circumstances of the moment are observed.

For example, Jim (child's pseudo-name) could have the habit to touch his ear when he starts getting tired. This habit creates an opportunity for new situations (new frames) to emerge when Jim happens to have a phone receiver in his hand while he touches his ear, as he usually does when he gets tired. The mother, at that moment, may spontaneously highlight Jim's action by bringing her own hand to her ear and saying, "Hello, am I talking to Jim?" This spontaneous activity captures Jim's attention: he looks at his mother, but nothing more, as he appears to be tired and starts becoming fidgety. This incident is, one could assume, forgotten. At that moment, it constitutes a small variation that maintains the usual relational routine of Jim touching his ear when he's tired. However, next time Jim and his mother play with the phone, the mother pays particular attention to the way Jim is wavering with the receiver. Specifically, any movement of the phone to his ear is highlighted by the mother and used as an opportunity to reconnect to the incident of the earlier session. These small variations in the dyad's relational routine initiate what subsequently will become a new sub-frame of the telephone frame, we may call it a "hello game". Over a few sessions, this "hello game" becomes a semi-stable routine as the mother introduces the socio-cultural significance of the phone in their play. Furthermore, one could assume that Jim had other phone experiences outside the telephone frame by watching phone conversations of adults.

We may conjecture that Jim's experiences outside the telephone frame coupled with his experiences with his mother within the telephone frame facilitate his recognition of the "hello game", thereby giving it a social significance through the mother's participation in the game. Thus, exchanges of gazes, smiles, surprise facial expressions, recurrent particular verbal phrases (such as "Hello, is it grandma calling?") become elements of the co-regulation, over time, of the routines that eventually lead to a new kind of understanding of the situation. This new understanding, we argue, involves a mutual recognition of the experience of the other as similar to one's own experience of the situation; that constitutes the essence of what Trevarthen coined secondary intersubjectivity. In other words, *shared experiences* over time have contributed to a mutual understanding of these telephone experiences as indeed shared. It is important to note, however, that this early understanding is, at the outset, limited to the frame in which it has emerged, that is, it's a *situated* shared experience. Only when the same mutual understanding has emerged in many different frames will the child achieve a more generalized secondary intersubjectivity that goes beyond the child's situated experiences.

In dynamic systems terminology, when the accumulated shared experiences within a frame are sufficiently elaborated, they will re-organize (i.e., self-organize) into mutually recognized shared experiences. It is our contention that the relational-historical approach, with its emphasis on the concept of self-organization, frames, and co-regulation, allows us to capture the build-up of situations where secondary intersubjectivity becomes possible. In other words, instead of assuming secondary intersubjectivity as the maturation of a general capacity of the human mind, we propose that secondary intersubjectivity first emerges through context-specific mutual understanding of concrete situations (referred to herein as frames), with its particular relational history, that later becomes generalized to other relational situations and becomes less context-specific.

Conclusion: Self-Organization in a Time Perspective

In this chapter we have elaborated on two different, but linked paradigmatic approaches to development, discussing their methodological implications for research on infant development: Epigenesis and Dynamic Systems approaches. The concept of development has been taken seriously, that is, has been understood as the change processes an individual goes through in his or her first years.

Epigenesis, as understood here, accounts for ontogenesis as well as microgenesis, integrating all levels of human functioning, from the genome to society and culture. Epigenesis accounts for the relationships between levels, mutuality of their influences, and their unity as the basis for understanding ontogenesis as well as microgenesis. Epigenesis also accounts for the relationship between past and present, pointing towards the future. That development has an historical dimension is crucial to the understanding of the present situation and state of any individual, including an infant. Epigenesis also accounts for the relationship between the individual and his or her outer environment, physical, and social. It also provides an understanding of the relationship between levels, where the immediate superordinate level becomes environment for the subordinate level chosen as the unit of analysis. For example, when the cell is the unit of analysis, you cannot take environment to be the environment external to the individual. That environment is mediated by the chemical substances, whether hormonal, nutritional, etc. with which the cell has a continuous exchange. At the level subordinate to the cell as the unit of analysis, the constituents of the cell, nucleus, cytoplasma etc, are components of the cell as a system that have a certain relationship to each other. The same holds true when you are choosing the dyad mother-infant as unit of analysis. Mother and infant are components of the system linked to each other through a certain relationship. Toys, the highchair, other persons in the room, etc. are environment. In both these examples, development is accounted for in terms of an history—of the cell, or of the dyad—that is crucial for the understanding of the change processes that are taking place in present time.

While epigenesis, as understood here, accounts for the historical dimension of development, dynamic systems approaches (DSA) account for the conditions for change processes. They provide theoretical concepts for the relationships between component in a system and stipulate the distinction between system and environment to be epistemological, not ontological, that is, it is the researcher choosing a unit and level of analysis that determines what is to be considered as system and what should be environment, dependent upon the research question to be addressed. More importantly, the concepts proposed by DSA, order parameter, control parameter, attractor state, phase shift, account for both stability, and change in the system over time.

Within the DSA that we have chosen to call mathematical, and where some simple variable, the control parameter, regulates phase shifts in the system, it is at least theoretically possible that "the same" critical conditions may recur. We caution to point out that the principle of the irreversibility of time is still valid for a "mathematical DSA", the possible "return" to an earlier state is actually not a return, but a case of recurrence of the same conditions at a later time (see, however, Witherington, 2007, for an alternative view). In the development of an individual organism, that will never be the case. In the life cycle of the organism, similar—or identical—external circumstances can never cancel out the fact that the organism will not be the same, that its history might have set new conditions for its way of responding to the external circumstances.

As an example of dynamic *methodology* (as opposed to dynamic theory) in infant research we therefore have found the historical-relational approach more appropriate than the experimental approach chosen by Thelen's team, for instance, in the research on the A-not-B error. For the study of infant development in a socio-cultural context, as we have illustrated earlier with our own work, we see a *combination* of the epigenetic view and DSA as the proper theoretical foundation for the dynamic methodology. The epigenetic view accounts for the historical dimension that is central to the historical-relational approach. It also provides a coherent model for the interconnectedness of the different levels of analysis, putting the dyad as the unit of analysis into a context that covers all levels on which the mother-infant interaction have an impact. DSA, on the other hand, provides the concepts accounting for the developmental processes themselves, concepts accounting for stability as well as change, and for the relationship between stability and change implicated in the concept of frame. History does not only consist of revolutions, phase shifts. It also consists of repetitions, continuity, and gradual refinement of skills and smoothness of co-regulations. We hope to have been able to demonstrate, using our own work as illustrations, that the concepts of attractor, emergence, and first and foremost self-organization nicely complement the mutuality, levels of interconnectedness between levels, definition of system and environment, and specification of the historical dimension offered by the epigenetic view of development.

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