CHAPTER THREE

Using Microgenetic Designs to Study Change Processes

Manuela Lavelli, Andréa P. F. Pantoja, Hui-Chin Hsu, Daniel Messinger, and Alan Fogel

The process of change represents a main, central issue for the study of development. Basic and applied researchers in developmental science have aimed their research work at answering several key questions related to the problem of change. How does change occur? What mechanisms produce change? What conditions are likely to promote the emergence of change in development? Another related question concerns the stability versus instability of new behavioral patterns that emerge as a consequence of an intervention. What are the relationships between variability and stability in developmental processes? Does the emergence of new behavioral patterns tend to suppress the old patterns or to coexist with them? Nevertheless, observing and understanding how change occurs has been recognized to be a quite difficult and challenging task (Miller & Coyle, 1999; Siegler & Crowley, 1991). This is despite recent advances in both theoretical perspectives and methods focused on change processes that have brought considerable progress in the research field (see "Microgenetic designs as promising tools," below). Part of the challenge is due to the complexity of conceptualizing change processes. It is our contention, however, that the main problem appears to come from the difficulty of devising and implementing appropriate methods for studying change *while* it is occurring (Fogel, 1990; Kuhn, 1995; Siegler, 1995), instead of comparing pre- and post-change behavioral patterns.

In this chapter, we aim to illustrate a research design, referred to as microgenetic designs, specifically devised for documenting change processes in development. First, we discuss the limitations of traditional research designs to capture ongoing processes of change. We then present microgenetic designs through an illustration of their key characteristics. This is followed by a review of the theoretical foundations of microgenetic designs as well as some of the historical and current observational and experimental studies based on microgenetic designs, illustrating their possibilities. In particular, we give a detailed presentation of the relational-historical approach as a particular form of microgenetic design devised to study developmental change processes in interpersonal relationships. Examples from our studies are given to illustrate the steps of a research program informed by the relational-historical approach. In the following sections of the chapter, we describe different quantitative and qualitative strategies that can be used to analyze data collected through microgenetic designs. Finally, we discuss the advantages of using microgenetic designs, suggesting new directions for microgenetic research.

Traditional Designs versus Microgenetic Designs

The main methodological difficulty in studying developmental change processes is that traditional research designs do not involve a direct observation of change *while* it is occurring (Kuhn, 1995). In both cross-sectional and longitudinal designs the researcher can see the *products* of change, not the *process*. Essentially, what these kinds of designs do is to compare the infants' or children's target behavior (e.g., the interactive behavior, or the behavior shown during a task) at different ages: cross-sectional studies compare the behavior of different children, whereas longitudinal studies compare the behavior of the same children at different ages. On the one hand, cross-sectional designs provide information on the characteristics of the target behavior in large groups at different ages. On the other hand, longitudinal designs yield important information on changes within cases, allowing one to compare those changes across different cases. Consequently, longitudinal designs afford more opportunities for the researcher to obtain insight on patterns of stability/instability of multiple individuals over time. Nevertheless, due to their time-consuming nature, longitudinal designs are often based on a small number of observations collected at widely spaced intervals. This strategy, however, has the potential to mask the intra-individual variability that is so important for those interested in how change occurs.

Another related limitation in most longitudinal designs is that the time interval between observations is usually too long to capture the ongoing process of change. Thus, the kind of information gained by such longitudinal designs is more like that in a series of a few snapshots taken across a wide span of time than the continuous flow of information in a movie (Siegler, 1995). As a result, transitional behavioral patterns, such as pre-reaching movements (Thelen et al., 1993) and strategies for adding numbers (Siegler & Jenkins, 1989), developed in brief periods of rapid change that could help clarify how infants/children make a transition in a specific domain may be completely missed using a "snapshot" approach.

Microgenetic Designs as Promising Tools

One promising approach to studying change processes and individual differences in development is offered by microgenetic designs as these are specifically aimed to allow the researcher to closely observe *processes of change*, instead of *products*. As the name implies, microgenetic designs are focused on the *microgenesis* of development, that is, on the moment-by-moment change observed within a short period of time for an elevated number of sessions. Usually, the observational time includes relatively short (weeks, months) but rapidly changing developmental periods.

Two main premises underlie the use of microgenetic designs. The first is that only by focusing on the *microgenetic details* of children's (and their partners') behavior in particular contexts (e.g., interactive and/or task-oriented contexts) is it possible to gain the type of fine-grained information that is necessary to understand change processes. The second premise is that observing and understanding changes at the micro-level of real time is fundamental to understanding changes at the macro-level of developmental time. This premise is rooted in Werner's (1948) hypothesis on the commonalities underlying changes that occur on different time scales, and strengthened by recent advances in the dynamic systems perspective within developmental science (see "Theoretical foundations and current studies," below).

Although the term "microgenetic method" has been predominantly associated with research within a more cognitive orientation, researchers of different theoretical perspectives have also advocated and adopted microgenetic designs. Only in the last decade, however, has the use of microgenetic designs been increasing and widening to investigate a range of different domains. Some of these domains include early emotional development (e.g., de Weerth, van Geert, & Hoijtink, 1999; Messinger, Fogel, & Dickson, 1999), mother–infant communication (e.g., Hsu & Fogel, 2003; Lavelli & Fogel, 2002), motor development (e.g., Thelen et al., 1993), early language development (e.g., Ruhland & van Geert, 1998), social writing (Jones, 1998), attention (Miller & Aloise-Young, 1996), memory (Coyle & Bjorklund, 1997), young children's problem-solving strategies (Chen & Siegler, 2000), and the effects of instructional procedures (Siegler, 2002). Such "explosion," we believe, is probably due to advances in both theoretical perspectives and data analysis strategies for the study of change processes. But what characterizes microgenetic designs?

Key characteristics of microgenetic designs

Regardless of the researchers' theoretical perspectives and the developmental domains under investigation, microgenetic designs are defined by the following key characteristics:

1 Individuals are observed through a period of developmental change. That is, the *changing individual* is the fundamental unit of analysis.
2 Observations are conducted *before*, *during*, and *after* a period during which rapid change in a particular domain occurs. That is, observation is not simply conducted before and after the change takes place.
3 There is an *elevated density* of observations within the transition period. That is, observations are conducted at time intervals that are considerably shorter than the time intervals required for the developmental change to occur. For instance, if a

developmental change takes place over several months, then observations should be conducted weekly or even more frequently (Fogel, 1990, 1997).

4 Observed behaviors are *intensively analyzed*, both qualitatively and quantitatively, with the goal of identifying the processes that give rise to the developmental change (Siegler & Crowley, 1991).

In the existing developmental literature, the change in behavioral patterns examined in observational studies is most likely to occur spontaneously, whereas in experimental studies, the change is most likely to be elicited. Either way, the goal of microgenetic designs is to accelerate the change process, or carefully observe the change process, by providing participants with a high concentration of experiences and opportunities, over a relatively short period of time (weeks, months) (Kuhn & Phelps, 1982). Of particular note, this strategy has been claimed as extremely useful to test potential control parameters, that is, those factors that according to a dynamic systems perspective shift the observed system into new behavioral configurations (see Thelen, 1990). In the case of changes that are hypothesized to occur across years, microgenetic designs also appear to be a useful alternative provided that a sampling of behaviors over a long period of time would be very expensive and time-consuming. But what are the theoretical roots of microgenetic designs? Microgenetic designs, especially microgenetic experimental designs, are deeply rooted in the history of developmental science. Their foundations are found within different theoretical perspectives.

Theoretical Foundations and Current Studies

Around the mid-1920s, the term "microgenesis" was coined by Werner as an extension of the German word *Aktualgenese* used by Sander (Leipzig group of Gestalt psychologists) to describe an experimental technique devised to evoke the genesis and development of percepts in the laboratory setting, thus yielding development as an object of observation for the researcher (Catan, 1986).

Werner shared the same interest in experimentally evoking developmental phenomena to closely observe them. Hypothesizing similarities between change processes at different developmental levels, Werner (1948) devised a set of techniques to scale down developmental phenomena of different extensions in time and at different developmental levels to experimentally reconstruct what he called "microgenesis," i.e., the activation and the developmental process of a particular competence in a miniaturized, accelerated form. Werner's work was cited and supported by Vygotskij (1978).

According to Vygotskij, macrodevelopmental changes (changes that occur over months and years) arise from the process of microdevelopmental changes (changes that occur over real time) observed in the context of social interactions. The interactions between a child and a supportive adult lead to questions, examples, and demonstrations that gradually change a child's performance, thereby allowing the child to perform activities that s/he could not accomplish alone. Thus, within this sociocultural perspective, a microgenetic analysis of the moment-to-moment changes observed during social interaction is used as a dynamic assessment of a child's "zone of proximal development." The microgenetic method also operates as a means to explore the mechanisms through which cultural factors structure the organization and development of the individual's communicative and cognitive strategies.

Current microgenetic approaches guided by sociocultural theory

The sociocultural theory discussed above represents a conceptual framework guiding some of the current studies using microgenetic analyses to investigate the development of problem-solving strategies in social-collaborative contexts. Compared to those studies that investigate the effects of collaboration on cognition using pre- and post-test designs, studies using microgenetic analysis present the advantage of gaining a wide range of information about the *process of change* in both the ensemble and the individuals. In these microgenetic studies, the natural course of the partners' behavior is videotaped over the time of one or more problem-solving sessions, and later analyzed in detail. Provided that such cognitive processes are expressed verbally and non-verbally through the joint activities observed during interaction, microgenetic analysis allows the researcher to track and correlate specific moment-to-moment changes to the changes observed in the participants' cognitive performance (Miller & Coyle, 1999).

For example, in preschoolers, microgenetic analysis has been used to document the transition from other-regulated to self-regulated problem-solving strategies (Wertsch & Hickmann, 1987; Wertsch & Stone, 1978). With regard to graduate students in a problem-solving interaction, microgenetic analysis showed that the microdevelopmental sequence (i.e., the moment-to-moment progression in understanding an unfamiliar device; Granott, 1993) followed the same progression predicted at skill levels by dynamic-skill theory, demonstrating a parallelism between microdevelopments and macrodevelopments (Fischer & Granott, 1995).

In the late 1970s, the spread of Vygotskij's theory associated with the shift in developmentalists' attention to microdevelopment within adult–child interaction constituted a turning point in the explosion of microgenetic designs to investigate change processes in social contexts. Examples include a study by Bruner (1983), where the ontogenesis of speech was examined through careful observation of two mother–infant dyads during spontaneous play every other week from 3–5 to 18–24 months. Studies conducted by Fogel (1977; 1985), Trevarthen (1977), and Papousek and Papousek (1984) also provided detailed documentation of the development of mother–infant face-to-face interaction through weekly or even more frequent observations of parent–infant dyads between the second and the sixth months of life.

Post-Piagetian microgenetic approaches to cognitive development

The emergence of microgenetic designs within the context of post-Piagetian studies was primarily affected by the work of Barbel Inhelder and Annette Karmiloff-Smith, who turned their attention from Piaget's general and atemporal analyses of cognitive structures to real-time analyses of the procedures and strategies that children generate in specific task situations (Inhelder et al., 1976; Karmiloff-Smith, 1984). These scholars highlighted the importance of examining the intimate relationship between changes at the micro-level (e.g., the processes through which a child reaches the solution of a particular problem during an experimental session) and changes at the macro-level (e.g., the participant's general cognitive systems for encoding reality), advocating an in-depth microgenetic approach. Such an approach, as Karmiloff-Smith observed (1993), has had important repercussions for Anglo-Saxon researchers, who turned their interest from the analysis of *products* to the analysis of *processes*. This shift is reflected on the developmental analyses focused on the microgenetic details of how children solve tasks, rather than whether their answers are right or wrong.

Such analyses allowed investigators to uncover that some of the children who gave a wrong answer during simple numerical and conservation tasks also showed a discrepancy between their verbal output and their non-verbal gestures during problem-solving (Alibali & Goldin-Meadow, 1993). The simultaneous expression of conflicting beliefs through verbal and non-verbal outputs was thus hypothesized and demonstrated to be an index of a transitional state of cognitive change (Goldin-Meadow, Alibali, & Church, 1993).

The use of microgenetic designs within the area of cognitive development has also revealed other interesting phenomena related to change processes and the conditions that precede a developmental change, such as the coexistence of multiple strategies, switching strategies within a single trial, and utilization deficiencies (see Miller & Coyle, 1999, for a review), recently observed also in toddlers' behavior during a tool-use task (Chen & Siegler, 2000).

Dynamic systems perspective within developmental psychology

The most recent theoretical foundation for microgenetic research is represented by the application of the dynamic systems perspective – i.e., an interdisciplinary approach that provides a model for the study of change processes – within developmental psychology (Fogel & Thelen, 1987; Thelen & Smith, 1994; van Geert, 1994). Substantially, the dynamic systems perspective aims to address the problem of describing, and thus explaining, the ways in which complex systems (including biological systems such as individuals) change over time. The focus is on how changes at the micro-level of relationships between a system's constituents give rise to new patterns of behavior at macro-levels. Accordingly, new patterns of activity emerge from the mutual relationship between constituents coming from the individual and environment, and not from a maturational or teleological plan within the individual. Due to the property of self-organization characteristic of complex systems, the constituents of a system act together to constrain the multiple actions of other constituents so that the complex system coheres into stable patterns of behavior called "attractors" (Prigogine & Stengers, 1984). Action schemes, emotions, and cognition as well as communication patterns in social systems can be conceptualized as attractors (Fogel, 1993; Lewis, 1995; Thelen, Kelso, & Fogel, 1987). Most attractors are dynamically stable; that is, although attractors constitute processes of change that occur in time, they preserve their integrity across a wide variety of conditions. This dynamic stability implies processes of both stability and change between attractors. Therefore, from a dynamic systems perspective, development is conceptualized as the reorganization of prior attractors and the emergence of new attractors through self-organization processes observed at the micro-level (Fogel & Thelen, 1987; Thelen & Smith, 1994).

Two different models have arisen within the dynamic systems perspective: a model based on quantifying the physical parameters of a given system, and a qualitative model focused on the information that is present in systems (Pattee, 1987). According to the physical-quantitative model, stability is observed when changes at the micro-level are maintained within the boundaries of existing attractors. A transition to a new attractor occurs when a change in the relationships among the constituents of a system reaches a critical value that takes that system beyond the boundaries of their existing attractors (Lewis, 1995; Prigogine & Stengers, 1984). For example, the rapid deposition of subcutaneous fat in the first postnatal months, and then the overtaking of a critical fat/muscle mass or strength ratio in the infant's legs was found to be a crucial control parameter for the "disappearance" of newborn stepping reflex (Thelen, Fisher, & Ridley-Johnson, 1984).

According to the information-qualitative model, changes in the constituents of a system at the micro-level create the conditions for the emergence of new attractors. Thus, the transition to a new attractor occurs when new information is generated; that is, when the difference generated within microchanges is perceived as meaningful or "a difference that makes a difference" (Oyama, 1985). For example, if the infant turns his/her gaze away from the mother, looking at a toy, and the mother perceives this change as a momentary disengagement of attention, she can then try to regain her infant's attention by using other familiar actions that have been previously successful. If, however, the mother perceives the change in the infant's gaze as a new interest (i.e., meaningful difference), she may follow her infant's gaze, picking up a toy, and showing its properties to the infant. Through these meaningful microchanges, a new pattern of communication emerges based on play with objects (Fogel & Lyra, 1997). This example illustrates that the process of transition between attractors in real time is thought to be a source for developmental change.

Whether within a physical-quantitative model or informational-qualitative model, microgenetic designs are advocated as imperative to understand how, in certain conditions, changes at the micro-level maintain a system's relative stability, while, in other conditions, microscopic changes give rise to developmental innovations. Accordingly, the process of developmental change is best revealed when researchers focus on key developmental transition periods, and intensive observations are conducted before, during, and after a key developmental transition (Fogel, 1990; Thelen & Ulrich, 1991). This is because the often fortuitous contingent series of events that give rise to a developmental change are most likely to be observed through frequent observations during periods of increased variability, or transition periods (Fogel, 1995, 2000).

Microgenetic research informed by the dynamic systems perspective has been leading important advances in understanding change processes in early infant development. Physical-quantitative models have often examined main motor developmental transitions observed during the first year of life. For example, to investigate the onset of reaching, Thelen and collaborators observed four infants in a standard reaching task and in a play session with their parents weekly, from 3 to 30 weeks of age; that is, before, during, and after the transition to reaching (Spencer et al., 2000; Thelen et al., 1993). Microgenetic analysis afforded opportunities for the discovery of dramatic individual differences not only in the age of reach onset – ranging from 12 to 22 weeks – but also in the strategies used by the infants to get the toy.

Due to the limited success of quantitative models in capturing the element of meaning/information inherent in interpersonal communication, a particular approach to microgenetic research has been recently devised by Fogel and collaborators (Fogel, 1995, 2000; Fogel & Lyra, 1997) to document change processes in interpersonal relationships. This methodological approach will be presented in detail in the next section.

Microgenetic Designs to Study Interpersonal Relationships: A Relational-Historical Approach

Based on the dynamic systems perspective and recent advances in life history qualitative research as well as quantitative methods to study change, a new methodological approach, referred to as the relational-historical approach (Fogel, 2000; Fogel & Lyra, 1997), uses microgenetic designs to study developmental change processes in interpersonal relationships. The approach rests on the assumption that interpersonal relationships have regularly recurrent patterns that regulate the communication and emotional closeness of the participants. Within a dynamic systems perspective, these patterns of communication between interactive partners are attractors in a relational landscape. Further, part of the developmental process of relationships includes historical process constituted by patterns of communication as they are formed, maintained, transformed, and dissolved over time. It follows, then, that an important assumption of this methodological approach is that relationship patterns repeatedly observed over a period of rapid change constitute the minimum unit of analysis. Another important assumption is that real-time changes may represent significant innovations for the participants, and thus have the potential to launch developmental changes.

Compared to other current microgenetic approaches, the contributions of the relational-historical approach include a focus on relationship patterns (rather than single components of relationships), and a historical perspective of change processes (provided that change is viewed as arising out of earlier system processes, although not entirely constrained by those processes). Thus far, this approach has been applied to study change in early mother–infant relationship within normally developing dyads across major developmental transitions reported in the literature. It is our contention that the relational-historical approach can be fruitfully extended to clinical populations. It is also suggested that it can be applied to analyzing change processes in relationships in periods of crucial transitions across the life span such as the transition to parenthood, first experiences of a child in a day-care center, family dissolution, or the child–therapist relationship in a process of physical rehabilitation.

The relational-historical approach includes the following main characteristics:

1 use of multiple case study method;
2 intensive observations across a key developmental transition;
3 identification of patterns of communication (referred to herein as "frames");
4 use of quantitative analyses of real-time sequences and developmental trajectories of patterns of communication combined with qualitative descriptions of the historical emergence of change and stability within dyadic communication.

Multiple case study method

The relational-historical approach is guided by the assumption that as the researcher invests time in multiple intensive observations of a small number of cases, there are considerable opportunities to observe in great detail the dynamics of change (Fogel, 1990; Thelen, 1990; van Geert, 1994). On the contrary, when time and resources are divided across many cases, as in more traditional research designs, it is inevitable that fewer observations can be made on each case.

The use of case studies in research inquiry refers back to the work of early baby biographers, who believed that only by collecting a substantial number of detailed case histories could general laws of development be constructed (Wallace, Franklin, & Keegan, 1994). Case studies have also been systematically used in the clinical literature, in Piaget's studies, in single-case behavioral analysis research, and in studies of language development (Thorngate, 1987; Wallace, Franklin, & Keegan, 1994). In all these kinds of case studies, the validity, meaningfulness, and insights generated from qualitative inquiry have more to do with the information richness of the cases selected and the observational/analytical capabilities of the researcher than with the sample size (Patton, 1990).

Furthermore, from a dynamic systems perspective, interpersonal relationships are thought to evolve through historical transitions between attractors, and it thus becomes essential to trace developmental trajectories of communication within each single relationship across developmental shifts. These individual developmental trajectories become the primary data source. Accordingly, once individual developmental trajectories are identified, it may be possible to compare and group subjects on the basis of developmental path, and not on the basis of developmental outcome (Thelen, 1990).

In one of our studies (Lavelli & Fogel, 2002), we documented the process of emergence of inter-dyad differences in early mother–infant face-to-face communication. Sixteen primiparous mother–infant dyads were videotaped weekly during spontaneous face-to-face communication at home, from age 1 to 14 weeks (i.e., before, during, and after the 2 months developmental transition). Developmental trajectories were traced for the duration of face-to-face communication as well as for other communication patterns observed in the data, using a multilevel modeling technique (see "Data analysis strategies applied to microgenetic designs," below). Results showed that the trajectories of mother–infant face-to-face communication were similar and increasing during the early weeks of life, but diverged around 2 months. After the second month of life, two different groups of dyads were identified on the basis of their developmental trajectories: one group with trajectories that continue to increase in the duration of face-to-face communication, the other group with trajectories that peak and then begin to decrease. A first investigation of system factors that may have contributed to the trajectories' divergence uncovered significant differences between the two groups related to the duration of the infants' wakefulness, gaze at the mother, and emotional expression during the period immediately prior to the divergence of trajectories. These findings illustrate how individual differences can be profitably studied comparing the overall patterns of the individual developmental trajectories, and not only the individual outcomes. As a result, these findings point toward the benefits of using the multiple case study method.

Finally, the quality of data collected using the multiple case study method depends to a great extent on the relationship that investigators build up with the research participants. This is because multiple intensive observations require considerable commitment on the part of the families involved in the study. For example, in an intensive longitudinal data collection conducted by Fogel and collaborators, 13 mothers brought their infants to a laboratory setting weekly for the entire first year of the infant's life, biweekly for the second year, and in some other cases until the end of the third year. During that period, the research staff formed close ties with each mother–infant dyad, and during particular periods such as holidays or family crises, staff also helped mothers to arrange their activities to find time to go to the laboratory each week. The mothers thus became active collaborators, taking their role in the research very seriously.

Intensive observations across key developmental transitions

Another advantage of the multiple case study method is that the researcher can isolate a particularly interesting developmental transition in order to study how individuals, dyads, or groups navigate across that transition. The fundamental principle of microgenetic designs informed by the relational-historical approach is to isolate a key developmental transition – that is, a well-documented change in infant/child development – and then to study the corresponding change processes in relationship patterns (e.g., mother–infant relationship) before, during, and after the transition. Similarly, in applied research, a particular period of developmental intervention can be isolated to document change and stability in the relationship between child and educator, or child and therapist, before, during, and after the intervention.

In one of our research programs (Fogel, 1998), we aim to document the process by which individual differences in patterns of attention and emotion arise developmentally in infants' social relationships with mothers, by making intensive observations across key developmental transitions. Four key developmental transitions in the first two years of life are closely examined: the transition to exogenous control, coinciding with the onset of social smiling and an increase in the infant's gazing at mother, around 2 months; the transition to visually directed reaching and the onset of systematic interest in objects, around 4 months; the transition to conventional communication and the onset of shared attention and emotion between mother and infant, around 12 months; and the transition to mirror self-recognition and the onset of self-related attention and emotions such as mastery, pride, and internal state language, around 18 months.

For example, the dataset focused on the first transition was collected using weekly observations of face-to-face play from birth to $3^1/_2$ months of age in 16 mother–infant dyads. Preliminary analysis indicated that the emergence of smiling is coupled with the emergence of active attention to the mother's face during the second month, confirming the well-documented 2-month developmental transition (Lavelli & Fogel, 2000). Multilevel modeling further revealed that inter-dyad differences in the duration of face-to-face play emerged toward the end of the second month, supporting the hypothesis that individual differences emerge during periods of increased variability as developmental transition periods. These findings illustrate the importance of conducting intensive observations across transition periods. A third important component of the relational-historical approach is its use of frames as the minimum unit of analysis.

Frame analysis: identifying stability and change in patterns of communication

According to the relational-historical approach, interpersonal relationships are historically developing systems of communication characterized by a relatively small number of attractors that tend to be stable under the dynamics of the system self-organization. These patterns are called "frames" (Fogel, 1993; Goffman, 1974; Kendon, 1985) and constitute the minimum unit of developmental analysis. Frames are "segments of co-action that have a coherent theme, that take place in a specific location, and that involve particular forms of mutual orientation between participants" (Fogel et al., 1997, p. 11). For example, in the context of the mother–infant relationship, commonly observable frames are feeding, comfort, attention getting, protoconversation, greeting, attachment behavior, and various kinds of play. Different frames are historically coupled with each other through real-time transitional processes – that is, processes of change engaged by the participants when their relationship changes from one communication frame to another (Fogel & Lyra, 1997).

The variability of action within the same frame on repeated occasions indicates that frames, conceived of as attractors, have a dynamic stability. Each time a frame is reconstituted in a relationship, small variations in the participants' attention, location, co-orientation, or topic of communication create a sense of ongoing novelty within sameness (Fogel, 1993; Stern, 1985). At the same time, however, this intrinsic variability also represents the potential for another level of change, that is, microchanges that begin transforming the existing frame, thereby opening opportunities for the emergence of a new frame. Microgenetic designs are therefore used to capture developmental change processes in interpersonal relationships through the analysis of microscopic variability observed within and between communication frames. A particular procedure, called frame analysis (Fogel, 1998), was developed to accomplish this aim. Frame analysis consists of three phases:

1 the identification of the most frequently occurring frames in the data;
2 the coding of real-time onsets and offsets of frames from the videotaped records;
3 the observation of changes within and between frames through microanalytic coding of real-time sequences of actions within frames and transitional actions between frames.

With respect to frame identification, once the specific communicative situation and the level of analysis are set according to the aim of the study, frames can be identified and distinguished on the basis of four criteria:

1 the direction of the participants' attention;
2 the participants' location;
3 the participants' postural co-orientation;
4 the topic of their communication.

Taken together, these microscopic criteria aim to capture the relational quality of segments of interpersonal communication that cohere into relationship patterns.

Once frames are identified, the coding of real-time onsets and offsets of frames for all the observation sessions is essential. This second phase of the frame analysis provides important grounding for examining stability and change across the key developmental transition and for observing changes within and between frames in real time. It is during this second phase that inter-coder reliability is measured. The last phase of the frame analysis consists of the microanalytic coding of both the participants' actions within and between frames. This is necessary to examine the sequences and co-occurrences of actions within frames, as well as the types of actions that form the transitions between frames. Standard sequential analysis methods (see "Data analysis strategies applied to microgenetic designs," below) are thus used in combination with narrative descriptions of those real-time changes (see "Qualitative analysis applied to microgenetic designs," below). The goal is to shed some light on the microgenesis of change in interpersonal communication – that is, to examine those real-time change processes that open possibilities for a developmental change.

Combining quantitative and qualitative analyses

Once frames, actions within frames, and transitions between frames have been coded, they are amenable to quantitative analysis. The relatively small number of cases does not preclude the use of parametric statistical analysis because an elevated number of observations within cases is gathered. Although the results from studies guided by the relational-historical approach are not intended to be generalized to the larger population, statistical analysis can be used as a means to identify regularities across cases. These regularities can then serve as hypotheses to be tested on larger samples. Further, the relational-historical approach rests on the premise that general principles of relational developmental change can be ascertained by studying each dyad separately. This allows the researcher to learn about both commonalities and differences between dyads in their developmental *process*.

In our studies guided by the relational-historical approach, we apply recently developed techniques to examine complex sequential processes in both real time and developmental time. These include, but are not limited to, the study of developmental trajectories for the real-time durations of frames and actions within frames using multilevel modeling (for more details, see "Data analysis strategies applied to microgenetic designs," below). When examining communication processes quantitatively, however, part of the methodology requires the breakdown of events into discrete sequences of codes for "individual" action. Therefore, since within the relational-historical approach codes are initially defined as relational actions, and analysis of sequences and co-occurrences arises from the theoretical recognition of action as relational-historical, the burden is on the investigators to guide the reader from the details of technique back to a relational-historical interpretation. One way to accomplish this is to combine quantitative approaches with qualitative analysis. One of the goals of the qualitative-narrative analysis is to place the quantitative findings into a historically coherent relational whole. The focus is then on the examination of frames as globally stable dynamic patterns. The quantitative analyses can provide a picture of systematic changes in frequencies and durations of frames, actions within frames, and frame transitions. The qualitative-narrative analysis thus complements the understanding of change processes as it can reveal whether the newly emerging frames arise from innovation introduced into the historical background frames (for more details, see "Qualitative analysis applied to microgenetic designs," below).

As mentioned earlier, the primary goal of applying a microgenetic design is to investigate change processes and individual differences in development. Due to the requirements of a microgenetic design, such as coverage of a developmental transition in its entirety, high density in time interval of data collection, and the intense nature in data extraction (e.g., microanalytic behavioral coding), the resultant quantitative data are characterized by smaller sample sizes and a larger number of observations. These features are different from data collected by applying a traditional longitudinal design, which are typically characterized by large sample sizes from just a few data time points. Therefore, a variety of unique data analysis techniques are called for. The next section provides an overview of data analysis strategies for detecting both developmental and real-time changes utilizing microgenetic designs.

Data Analysis Strategies Applied to Microgenetic Designs

Detecting within- and between-individual differences in developmental changes

Four different data analysis strategies have been applied to analyze data collected based on a microgenetic design:

1. normative-oriented approach, in which developmental changes are determined by group averages;
2. idiographic individual-oriented approach, in which replication of findings by multiple cases is the focus of investigation;
3. individual growth-modeling approach, in which detecting the shape of the developmental trajectory is the primary interest;
4. multivariate individual-oriented approach, in which the pattern of change is investigated on the basis of an array of indexes with a single individual and replication with multiple cases over time.

Of particular note, all four strategies are applicable not only to observational data but also to any quantitative data extracted from diaries, interviews, case reports, and questionnaires.

Normative-oriented approach This approach refers to using the individual as the unit of analysis and summarizing across individual analyses to make generalizations about groups or subgroups of individuals over time based on the central tendency. Repeated-measures analysis of variance, with the time variable as the within-subjects factor, is a typical strategy. Trend analysis can then be performed to fit the orthogonal polynomials to specific developmental curves in detecting the developmental trajectory of the group of individuals in the follow-up analysis.

Due to the intensive nature of a microgenetic design, individuals are observed at many more time points than in a traditional longitudinal study. In order to apply repeated-measures strategies, data need to be collapsed to reduce the number of levels of the time variable. A repeated-measures ANOVA method is the dominant approach in psychological research for the examination of developmental change (Hertzog & Rovine, 1985). This strategy is simple and straightforward, and can be easily performed with many off-the-shelf statistical packages. Nevertheless, despite the fact that the unit of analysis is the individual, the result of analysis is only pertinent to individuals as a group. As a result, information pertinent to each of the individuals is missing. Only the normative pattern of developmental trend based on central tendencies is revealed at a group level, which may not reflect the developmental change of any individual in the group (Bates & Appelbaum, 1994).

Idiographic individual-oriented approach Focusing on within-individual differences, this approach refers to empirical investigation of individuals and their correlates over time in psychological research (Jaccard & Dittus, 1990). Like the normative-oriented approach, the unit of analysis in an idiographic approach is the individual. However, instead of performing statistical analysis with individuals at a group level, the analysis is performed separately for each individual case by case. Results from each individual are then later summarized or aggregated to show the overall pattern of within- and between-individual differences in development. In essence, a multiple case study method is applied in this approach.

Graphical display and visual inspection of individual data against time (e.g., daily or weekly) have been suggested as the first step for analysis (Bakeman & Robinson, 1997). However, visual analysis is notorious for its subjectivity, unreliability, and insensitivity in detecting less pronounced changes. Statistical evaluations are often desirable tools to detect whether a significant change has occurred or whether a developmental pattern has emerged (Busk & Marascuilo, 1992; Franklin et al., 1996). Two alternative statistical techniques are available for this case-by-case approach: ordinary least-squares regression and polynomial regression.

Ordinary least-squares regression analysis can be applied to detect linear patterns of developmental changes. Linear regression analysis may be performed separately for each mother–infant dyad to reveal the developmental trajectory of different behavioral patterns (see Messinger, Fogel, & Dickson, 1999). Polynomial regression analysis can also be utilized to approximate the nonlinear developmental trend within each individual (see de Weerth, van Geert, & Hoijtink, 1999). This case-by-case method not only preserves the individual as the unit of analysis, but also serves as replications within the same study. The replicating findings with multiple individual cases would reduce the likelihood of obtaining spurious results (Bates & Appelbaum, 1994). However, the drawback of this approach is that multiple tests of significance with several individuals may inflate the Type I error. To obtain an estimate of the significance at population level, a meta-analytic technique has been suggested (Glass, McGaw, & Smith, 1981, cited in de Weerth, van Geert, & Hoijtink, 1999).

An idiographic individual-oriented approach to data analysis can provide a wealth of information based on a case-by-case analysis of each individual. Unfortunately, the results from each of the individual cases under investigation do not necessarily yield a coherent single picture of the development. Systematic empirical examination of the similarities and/or differences among individuals is necessary. Deriving a valid and reliable coefficient of similarity is needed in future studies.

Individual growth-modeling approach This approach refers to the investigation of individual development within the context of a group of individuals, focusing on the shape of growth trajectories at both the individual and the group levels. This approach not only permits one to answer the "within-individual" level (level-1) research questions, but also allows one to unravel the "between-individual" level (level-2) research questions (Willett, 1997). At the within-individual level, the focus is on the developmental change within the individual. The questions are about the rate (e.g., dramatic or gradual increase) and shape (e.g., linear or curvilinear) of the development for each individual. At the between-individual level, the primary question is about whether the trajectory of developmental change is different from one individual to another, and about the individual and/or contextual characteristics that contribute to the between-individual differences in developmental trajectories. Furthermore, it may also be possible to address the question of whether individuals' developmental trajectories are predictive of different patterns of developmental outcome (see Nagin & Tremblay, 1999, for examples).

The growth-curve modeling method has been applied to examine early language (Huttenlocher et al., 1991), infant vocal development (Hsu & Fogel, 2001), and infant–mother interaction (e.g., van den Boom & Hoeksma, 1994). The sample sizes of these studies are relatively small ($N \leq 30$) and data were collected from more than 6 time points (the most intensive one has 20 time points). Several computer programs are devoted to performing the modeling of growth curves. MLn (Multi-Level analysis; Woodhouse, 1996) and HLM (Hierarchical Linear Modeling; Bryk & Raudenbush, 1992; see Chapter 18 for details) are the two commercially available programs. Results of a comparative study suggest that the available programs derive the same solutions for the estimated parameters (Kreft, de Leeuw, & Kim, 1990, cited in Willett, 1997).

Multivariate individual-oriented approach The approaches discussed above are primarily univariate methods – only one variable (measured repeatedly over time) is under consideration in the analysis. One might ask what if several variables are measured and collected repeatedly from the same individual over time. In this case, a multivariate approach would be necessary. P-technique factor analysis is a useful statistical strategy to examine within- and between-individual differences when a large number of variables are collected from a single individual intensively across time (Hooker et al., 1987; Jones & Nesselroade, 1990). This technique is different from a typical R-technique factor analysis, in which the patterns of variables (or factors) are formed on the basis of a group of variables collected from a large sample of individuals. The goal of P-technique factor analysis is to identify how groups of variables change together across time within the same individual. A minimum of 100 observations has been suggested for this technique (Jones & Nesselroade, 1990). The factor scores derived from the factors can be further examined for trends over time with linear or curvilinear orthogonal polynomials by follow-up analyses. Developmental changes in the underlying structure of the individual behaviors or characteristics can then be revealed. To replicate the findings from separate individuals, the degree of congruence of factor patterns between individuals can be performed by a congruence assessment (Harman, 1967). This evaluation of congruence reveals the between-individual differences or similarities. However, like univariate analysis strategies, autocorrelation within each variable from repeated observation with the same individual may distort the pattern of factor loadings in the P-technique (Gorman & Allison, 1997). Recently, dynamic factor models, which allow for autocorrelation, have been developed. Such models may be an alternative to the P-technique method (see Wood & Brown, 1994). In the next subsection, we provide data analysis strategies specifically used for measuring real-time changes.

Quantitative measures of real-time change

A precept of microgenetic methods is that real-time change occurring during an actual interaction or cognitive task sheds light on development. The quantitative methods reviewed here rest on the premise that by analyzing a behavioral stream into its constituents and examining how the constituents are organized, we can shed new light on the processes being observed. In this subsection, we review quantitative methods for understanding how behaviors are related in real time and summarize statistical methods for assessing developmental change and stability in these patterns. Our focus is on interactions between an infant and caregiver. But the methods reviewed can be generalized to other participants (such as a therapist and client) or generalized to the analysis of different behaviors of a single individual (such as a toddler in a non-interactive learning paradigm).

In all behavioral and interactive processes, we distinguish between at least two different streams or modalities of action. These might be the speaking turns of two adolescents or the facial expressions and vocalizations of a single infant. Codes are chosen to distinguish behaviors within each of these modalities (e.g., speaking and not speaking). Having coded one's data, there are different approaches to documenting associations between behaviors in time. We focus on:

1 measures of the overlap between two behaviors;
2 measures of the frequency with which one behavior occurs during another;
3 measures of the sequencing of two behaviors.

These measures of temporal association produce different but complementary views of behavior and interaction.

The overlap or co-occurrence of two behaviors may be the simplest and most common case of a temporal association in the developmental literature (e.g., Weinberg & Tronick, 1994). To illustrate, mother smiling and infant gazing at mother's face tend to occur simultaneously (Kaye & Fogel, 1980). This association can be documented by comparing the percentage of time in which mothers are smiling and infants are gazing at their mothers' faces with the percentage of time in which mothers are not smiling and infants are gazing at their mothers' faces (Messinger, Fogel, & Dickson, 1998). Alternate measures of temporal overlap are log odds and Yule's Q (Bakeman, McArthur, & Quera, 1996). All produce robust measures of the degree of co-occurrence between two behaviors.

Co-occurrences indicate that a pattern exists, but do not shed light on how it forms. To understand how co-occurrences form, it is useful to examine how frequently one behavior begins (or ends) during a different behavior. Continuing with the same example, mothers smile more frequently when their infants are gazing at them than when their infants are gazing elsewhere. Infants, however, do not gaze at their mother more frequently when she is smiling. In fact, infants gaze *away* from their mothers more frequently when their mothers are smiling than when they are not smiling. It appears to be mothers, not infants, who are most directly responsible for creating the co-occurrences between mother smiling and infant gazing at mother (Messinger, Fogel, & Dickson, 1998). This case illustrates how a frequency analysis can pinpoint the proximal source of a pattern documented by a co-occurrence analysis and, more generally, how different types of analyses can provide complementary perspectives on real-time interactions.

The stability of co-occurrence analyses can also be directly combined with the focus of frequency analyses (Messinger, Fogel, & Dickson, 2001). The idea is to document the overlap of two behaviors, but only when the overlap begins with the onset of the behavior of particular interest. In an illustrative example, we tabulated the proportion of time infants engaged in different types of smiling while their mothers were already smiling or not smiling. Only those co-occurrences that began with the infant engaging in a particular type of smiling were examined; co-occurrence that began with the mother smiling or ceasing to smile were not examined. Conceptually, this allowed us to focus on how infants smiled in response to their mother smiling, rather than the reverse (Messinger, Fogel, & Dickson, 2001). More generally, this case illustrates how different types of analyses of real-time behavior can be combined to focus on specific research questions.

One difficulty with both co-occurrence and frequency techniques is that they do not efficiently document complicated sequences involving two different behaviors. Yale and her colleagues (Yale et al., 1999) suggest an efficient schema for classifying the temporal overlap of two behaviors. One behavior can be embedded in the other. An infant, for example, can gaze at the mother's face, smile, then stop smiling, and, finally, gaze away from the mother. Alternatively, one behavior can begin during another but then outlast it. A smile, for example, can begin during a gaze at the mother's face but then continues, ending only after the infant has looked away from the mother. Different sequences of behavior can be tallied by hand or by using the display function of specialized software. The difficulty lies in determining whether specific sequences occur more often than expected by chance.

Newly developed simulation software surmounts this problem (Yale et al., 1999). The temporal progression or stream of actions is simulated independently within each behavioral modality. So, for example, actual periods of gazing at and away from the mother's face are combined in random order (with the proviso that the two actions always alternate) to create a simulated session. The simulated gaze session is combined with a simulated session of facial expressions created in the same fashion. The number of different patterns of gaze–smile sequences expected by chance in a given interactive session is determined by running the simulation repeatedly (e.g., 2,000 times). A summary z score is then created that indicates the degree to which a given infant at a given age sequences actions into a specific pattern at greater than chance levels. Simulation analyses are of great interest because they have the potential to document complex patterns of real-time behavior and (see next section) how they change with time.

The co-occurrence, frequency, and sequential techniques outlined above create summary measures of real-time behavior. Developmental researchers in general and microgenetically oriented researchers in particular are typically interested in how development occurs for an individual or within an interactive dyad. For this reason, it is optimal to calculate measures of relationship between two variables – measures of co-occurrence, frequency, and of sequential organization – for the individuals or dyads that comprise a sample. The same set of statistical tests can then be performed on all these measures of association. The binomial test indicates whether a higher proportion of participants show associations between behaviors than the proportion expected by chance (Hays, 1988). Parametric tests (e.g., t-tests and Fs from repeated-measure ANOVAs) indicate whether the mean level of association between behaviors is greater or less than that expected by chance. When measures of association are calculated repeatedly (as in a microgenetic design) they can be subjected to the longitudinal analyses discussed in the previous sessions. Qualitative techniques for exploring and documenting developmental change in these real-time patterns are the subject of the next section.

Qualitative Analysis Applied to Microgenetic Designs

Another crucial component of our microgenetic investigations includes the qualitative description of the historical emergence of change and stability within dyadic communication, using frames as the unit of analysis. The term qualitative analysis, however, refers to a broad range of techniques utilized by social scientists, including developmental scientists, who aim to explicitly include the interpretative nature of research inquiry into their investigations. Among the various forms of qualitative methods, we focus on Polkinghorne's (1995) discussion of narrative analysis because it has been helpful in providing tools for our developmental investigations of early mother–infant relationships.

Polkinghorne (1995, p. 15) defines narrative analysis as ". . . the procedure through which the researcher organizes the data elements into a coherent developmental account." Narrative analysis allows the real-time changes that constitute the developmental process of early mother–infant relationships to be captured as part of a historical and coherent whole. In order to adapt Polkinghorne's narrative analysis to our microgenetic investigations of early development, we have created a series of analytic steps that we utilize with our longitudinal videotaped data of mother–infant transactions (e.g., Pantoja, 1999; Pantoja, Nelson-Goens, & Fogel, 2001).

Narrative analysis steps

The first step of the narrative analysis consists of watching and re-watching each of the videotaped records of the mother–infant interaction. The goal is to develop initial impressions and interpretations of the unfolding of the dyad's communication development in the changing context of their relationships. This is important as it provides the investigator with a preliminary view of both stable and changing components of the mother–infant relationship.

As our second step, we create chronological narratives for each dyad – that is, the description of the observed phenomena in terms of sequences of events. As qualitative researchers, we recognize that as the investigator transforms the observational data into text, s/he may not describe every dyadic action occurring at the level of real time. The process of writing sequence narratives implies an interpretation. Similar to the decisions made during the identification of frames, the interpretation implied in the sequence narratives is guided and refined by the research problem in question.

In our third step, the sequence narratives become the main data. When the study includes multiple cases, the investigators inductively derive the frames by session for each dyad, and the frames that emerge from each dyad inform the other frames – this is an iterative process also known as the constant comparative method (Denzin & Lincoln, 1994; Strauss & Corbin, 1990).

The fourth step includes the rereading of the sequence narratives, bearing in mind the frames that originated from the previous step. The purpose is to create short stories that synthesize the meaningful elements of each session. With these short stories, we begin to configure the dyadic actions involved in early communication development by means of a preliminary plot that emerges from the data. We then move to our fifth step. The objective is to emplot these short stories into a narrative that synthesizes the *history* of communication development for individual dyads.

When the study includes more than one case, the goal of the final step is to capture the regularities, if any, across dyads in the way they develop and transform their relationship history over time (for an example, see Fogel, 1995). At this level, the investigator aims to create a story strongly "characterized by the integration" (Ricoeur, 1991, p. 22) of the multiple historical narratives. This is another level of narrative analysis in which the observer moves towards a synthesis of the multiplicity of events into a complete and meaningful story.

Concluding Remarks

This chapter presented microgenetic designs as a promising approach advocated by researchers of different theoretical perspectives to studying change processes in development.

At the beginning of the chapter, we introduced central issues related to the problem of change that traditional designs fail to address. Now, we synthesize the benefits of using microgenetic designs, considering how some of these issues can be tackled by such designs. We then discuss objections addressed to the use of microgenetic designs, as well as costs and limitations. Finally, we indicate new directions for microgenetic research.

Advantages of microgenetic designs

The studies described in the different sections of the chapter illustrate the kinds of issues that microgenetic designs can address that more traditional designs cannot. To synthesize, the focus on microgenetic details of the sequence of children's (and their partners') behavior during close observational or experimental sessions over a period of rapid change allows researchers a direct observation of the change processes. This includes the observation of short-lived transitional behaviors that would not be detected within more aggregated analyses. Microgenetic designs thus can address the issue of how change occurs, at least at the level of detailed descriptions of change processes, and convey both quantitative and qualitative aspects of change, shedding some light on the nature of transitional states.

Because of the density of observations, microgenetic designs allow researchers to trace individual developmental trajectories for a particular behavior across the age range investigated, thus highlighting stable and changing components of behavioral patterns. This allows for the identification of transition points from the prevalence of a behavioral pattern to the prevalence of another pattern that could not be detected through more typical longitudinal designs. Therefore, microgenetic designs allow researchers to investigate intraindividual variability; that is, to address the issue of stability and instability of individual behaviors across time and different conditions. As discussed earlier, such designs can also address the question of individual differences in the acquisition of new patterns of behavior both in terms of transitional strategies as well as rate and time of developmental changes.

Finally, microgenetic designs allow for the identification of the conditions under which changes are most likely to occur. As a means to closely examine the mechanisms underlying the change investigated, microgenetic designs allow researchers to formulate hypotheses about the potential parameters responsible for the change, and test their hypotheses through microgenetic experimental studies. Thus, microgenetic designs increase our understanding of change processes, fostering the possibility of explaining, in addition to describing, such processes.

New directions for microgenetic research

The elevated costs involved in microgenetic research make it essential that the period of intense sampling substantially coincides with a period during which the rate of change is particularly rapid. A research field within which the use of microgenetic designs is becoming particularly fruitful, because of the omnipresence and rapidity of change, is that concerning developmental processes during the very first years of life. Recent microgenetic studies on early emotional and communicative development, as well as motor development, are stimulating the widespread use of such designs by illustrating that they are leading to great advances in understanding early developmental change processes.

In addition, recent advances in dynamic systems perspective have been contributing to the theoretical support to use microgenetic designs as a means to document change and stability in development. Microgenetic approaches have been fruitfully extended to studying change processes in different domains of development, thereby highlighting new directions for enriching microgenetic research. We think that these directions are essentially represented by:

1 a research focus on naturally occurring behaviors in social contexts;
2 a focus on the communication and relationship between elements in a dynamic system, rather than a focus on a "disconnected" individual;
3 a historical perspective on change processes in which change arises out of the earlier systems processes.

We believe that, with recent advances in quantitative and qualitative techniques for analyzing the emergence of variability in developmental change processes, microgenetic designs can fruitfully be extended to studying multiple cases in different populations.

Finally, after outlining the costs and benefits of microgenetic designs in the context of developmental research, we would like to encourage clinicians as well as those interested in education and public policy to explore the possibilities of applying the microgenetic principles discussed in this chapter in their respective areas of interest. Some of the principles presented throughout this chapter may be particularly suitable to early intervention programs. How could we promote change and growth through simple manipulations in the everyday details that constitute the lives of children and families? This is a new direction for microgenetic research that is yet to be developed.

Note

Correspondence concerning this chapter should be addressed to the first author, Manuela Lavelli, Dipartimento di Psicologia e Antropologia Culturale, Università degli Studi di Verona, via S. Francesco 22, 37129 Verona, Italy. Electronic mail may be sent to manuela.lavelli@univr.it.

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