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# Microgenetic Analysis of Learning: Measuring Change as It Occurs

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**ABSTRACT**

**The ability to measure the process of change in learning represents a fundamental aspect of psychology. In this manuscript, initially, two traditional designs, cross-sectional and longitudinal, are shown to be inadequate for analyzing changes associated with cognitive learning processes. Then microgenetic analysis, along with its philosophical underpinnings and a case study, is shown to be a promising methodological approach for examining change processes and individuals' learning differences because it is expressly designed to permit researchers to scrutinize processes, not products, typically associated with cognitive change or learning.**

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## Microgenetic Analysis of Learning: Measuring Change as It Occurs

The ability to measure the process of change in learning represents a fundamental aspect of psychology. Researchers (Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005) who have studied the problem of change have focused their attention on answering several key questions: How is change per se manifested? What circumstances tend to hasten the emergence of change in learning? What mechanisms engender change? How stable are new behavioral patterns that evolve due to interventions? How are variability and stability in learning processes related? Do new behavioral patterns that emerge typically inhibit or coexist with old patterns? Despite the utility of these questions, analyzing how change occurs remains a daunting and challenging task for at least two reasons: first, conceptualizing change processes is complex. Second, and more importantly, designing and applying techniques appropriate for analyzing change while it is actually happening, rather than comparing behavioral patterns from a pre- and post-change perspective, is paramount (Fogel, 1990; Kuhn, 1995; Siegler, 1995).

## Purpose of the Article

In this article, microgenetic analysis is described by initially discussing traditional research designs' limitations in documenting changes' ongoing processes and then by presenting this design's pivotal features. Next, the theoretical underpinnings of microgenetic analysis are explained. Then a case study is used to illustrate how this research design captures the processes of change. Finally, conclusions are drawn.

## What is Microgenetic Analysis?

In this section, the problems associated with two traditional research designs, cross-sectional and longitudinal, for documenting change processes as they occur are first discussed; then the primary features and mechanisms which enhance microgenetic analysis' success at capturing ongoing change are described.

## Traditional Research Designs

According to Kuhn (1995), traditional research designs' major methodological flaw for analyzing learning change processes is that they fail to directly observe change while it actually occurs. Both cross-sectional and longitudinal designs permit researchers to view only the products, never the processes, associated with change. Both designs essentially compare children's target behavior at various ages: cross-sectional studies basically compare different children's behavior, while longitudinal studies, in contrast, compare the same children's behavior at various ages. More specifically, cross-cultural studies generate feedback on a target behavior's characteristics in large group settings at various ages. In contrast, longitudinal designs provide critical feedback on changes within cases, rendering a comparison of these changes across various cases feasible. Hence, longitudinal studies enhance the probability that researchers will derive insight on multiple individuals' stable/unstable patterns over time. Nonetheless, longitudinal designs are frequently based on a few observations that are collected over greatly spaced intervals because of their time-consuming nature. In addition, this design potentially conceals intra-individual variability, so essential for grasping specifically how change occurs. Another limitation of this design is that its lengthy time intervals between observations are too long to apprehend the progressive process of change. Thus, the information derived from this design is analogous to that of snapshots occurring across wide intervals of time rather than to the continual flow of information associated with movies (Siegler, 1995). Consequently, transitional behavioral patterns that evolve over short periods of speedy change, critical for ascertaining how, when, and why domain specific transitions occur, remain obscured due to a snapshot approach (Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005).

In the next section, microgenetic analysis, fortunately, is shown to be a promising methodological approach for examining change processes and individuals’ learning differences because it is expressly designed to permit researchers to scrutinize processes, not products, typically associated with change.

## Microgenetic Analysis

Microgenetic analysis (see Siegler, 2006, for a current review) converges on the microgenesis of learning, i.e., on the moment-by-moment change examined within a relatively short span of time for an increased number of meetings. The observational time, in fact, normally entails essentially short, usually weeks or months, but swiftly changing learning periods (Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005; Siegler, 2006).

Two major premises support the utilization of microgenetic analysis: First, the acquisition of microgenetic details of subjects’ behavior in specific contexts is the only approach that makes it possible to derive the kind of fine-grained information essential for grasping change processes. Second, the ability to apprehend macro-level changes of developmental time is basically contingent upon observing and comprehending micro-level changes of real time (Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005).

Three critical principles enable researchers who use microgenetic designs to confirm that close examinations of the nature of a transition is the sole approach for specifying how the mechanisms of change function (Flynn, Pine, & Lewis, 2006). First, researchers observe individuals throughout a span of developmental change, so that the changing individual operates as the basic unit of analysis. Second, observations are not conducted only prior to and after a change occurs; rather, periods characterized by rapid change in a specific domain are observed before, during, and after such a change occurs. Third, within the transition period, the density of observations must be elevated relative to the rate of the change, implying that the time intervals of the observations must be significantly shorter than the time intervals necessary for a developmental change to evolve. For example, a developmental change requiring several months to occur would call for weekly, or more frequent, observations (Fogel, 1997). Qualitatively and quantitatively intense analyses of observed behaviors facilitate identification of, and possibly accelerate, the processes responsible for developmental change (Siegler & Crowley, 1991).

According to Karmiloff-Smith (1993), microgenetic designs emerged during post-Piagetian studies because these researchers accentuated the significance of scrutinizing the close connections between micro-level changes (e.g., the processes utilized by a child during experimental sessions to solve a specific problem) and macro-level changes (e.g., an individual’s general cognitive system used to encode reality). This approach, furthermore, was principally responsible for switching Anglo-Saxon research from the products of change to the processes of change.

According to Siegler (2006), the microgenetic design’s increasing dominance is due in no small part to the fact that the precise data that it yields on cognitive change far outweighs the time and effort essential to elicit the data. As proof of this, he asserts that one need only look at how data derived from microgenetic designs have enabled researchers to investigate how children's discovery of novel strategies evolve, a fundamental issue relative to learning. For instance, microgenetic designs are the only developmental design that enables researchers to pinpoint the precise trial when an experimental subject utilized a novel strategy. Pinpointing the trial when a novel strategy was initially applied gives us excellent feedback regarding the nature of said discovery: Did the innovation excite the child? Was the child even cognizant about applying a new strategy? Was the child able to rationalize the advantageous nature of the new strategy? Pinpointing the trial when a novel strategy was initially applied enables researchers to examine the child's performance immediately prior to the discovery: What kinds of problems did the child confront prior to the discovery? Did the child succeed or fail to solve these previously mentioned problems? Did solving the problem require that the child use an inordinate amount of time? Furthermore, knowledge of when the discovery occurred also enables researchers to examine the child's performance immediately after the discovery: Did the child steadfastly apply the novel strategy on the identical kind of problem? Did the child extensively generalize the novel strategy to other problem types? To what extent did the child assiduously execute the novel strategy? Finally, how did the child's increasing acquisition of experience with this novel strategy change all of these performance dimensions? These aforementioned benefits are primarily responsible for the increasing appeal of the microgenetic design for many investigators who analyze children's learning.

## Theoretical Underpinnings of Microgenetic Analysis: The Overlapping Waves Theory

In order to capture the diverse findings relevant to the widespread variability of children's thinking when using various strategies to solve problems, Siegler (1996) set forth the overlapping waves theory. The co-evolution of this theory with microgenetic analysis has proven to be undoubtedly fruitful for the integration of research findings regarding the processes of change associated with learning. The overlapping waves theory's underlying assumption revolves around the notion that the analysis of cognitive change occurs along five dimensions: path, rate, breadth, source, and variability. The path of change focuses on how children sequence their predominant behaviors to gain competence; in other words, was change one of a qualitative or quantitative nature? The rate of change refers to the difference between the initial application of a novel strategy and its consistent application in terms of time and experience invested in the process, i.e., was it an abrupt or gradual change? The breadth of change concerns how extensively the novel strategy generalized or transferred to different problems and contexts. In other words, was it a domain-specific change or was the change generalizable across domains? The source of change pertains to the causes, or changes in behavior, that catalyzed the change. The variability of change concerns how children differ amongst each other regarding the other four dimensions, plus how individual children apply fluctuating sets of strategies. More specifically, how does one's behavior vary across comparable tasks within a specific domain? Also, do equivalent patterns of change exist across individuals?

## Case Study Analyzing How Children's Learning Changes

One of Siegler's (1995) studies focusing on the mastery of number conservation is used to illustrate how microgenetic analysis and the five dimensions of the overlapping waves theory can be used to generate in-depth information essential for increasing our understanding of the nature of change. In this study, five-year-olds who had been identified as not having yet mastered number conservation participated in four training sessions to address this shortcoming. During the study, three conditions were used to present children with conservation problems. Some children were provided with feedback only, regarding their answers. Others, however, were initially requested to explain their reasoning; then they were provided with feedback about their answers. A third group was initially provided with feedback regarding their answers; then the experimenter asked "How do you think I knew that?" (p. 234).

Due to microgenetic analysis, Siegler (1995) was able to identify the source, path, rate, breadth, and variability of cognitive change. Results indicated that the source of this study's most striking change revealed a combination of feedback relative to the appropriateness of answers and requests that the children provide an explanation of why the right answer indicated by the experimenter was right. This combination also produced greater learning than just feedback. The path of change focused on children who had been requested to explain the experimenter's reasoning. Initially, the children relied mostly on the relative length of each row of buttons; then, they went through a period characterized by the abandonment of this approach yet failing to adopt any invariable alternative. Ultimately, they frequently adopted the correct approach based on the kind of transformation (quantitative: adding, subtracting, or neither adding nor subtracting any items from the rows; spatial: lengthening or shortening rows or moving items back and forth in a row) conducted by the experimenter. There was a moderate rate of change. Several sessions were required by most children to advance from the initial application of the transformational strategy to the consistent application of the transformational strategy. There was a relatively narrow breadth of change. Even as late as the final session, some of the study's most capable learners continued to frequently propose length explanations, instead of transformational ones, of the experimenter's reasoning that focused on problems that had more objects on the longer row. Finally, the variability both within and between children proved to be substantial. Relative to within-child variability, a mere 2% of the children employed a single strategy throughout the four sessions; in contrast, three or more approaches were applied by 70% of the children. For the between-child variability, two pretest measures (total number of strategies that the child used and whether or not two different strategies were applied by the child on the same problem) predicted individual differences in learning. Hence, the findings of this study enabled Siegler to distinguish among the five dimensions of cognitive change, while simultaneously providing an appropriate framework to analyze children's learning.

## Concluding Remarks

Microgenetic designs, in contrast to traditional designs, not only allow researchers to directly observe change processes but also to observe short-lived transitional behaviors that would otherwise typically remain undetected within analyses of a more aggregated nature. In addressing the topic of how change evolves, microgenetic designs reflect facets of change along both quantitative and qualitative dimensions, while simultaneously elucidating the nature of these transitional states. Consequently, microgenetic designs facilitate the investigation of intraindividual variability, i.e., individual behaviors' stability and instability across time and varying conditions. The ability of microgenetic designs to facilitate researchers' ability to identify conditions most conducive for change to occur also enables them to formulate hypotheses regarding potential parameters associated with change, and to conduct microgenetic experimental studies to verify their hypotheses (Lavelli, Pantoja, Hsu, Messinger, & Fogel, 2005). According to Sielger (2006), detailed analysis of which mechanisms are associated with shorter versus longer time periods may signify that differences currently evident are actually more substantial. In articulating our understanding of how change occurs, microgenetic studies also enable us to both explain and describe such processes.

The rich and fined tuned data derived from microgenetic studies is essential for researchers to build formal models that articulately reflect cognitive development (Flynn, Pine, & Lewis, 2006). Hence, such models can make potentially significant pedagogic, or classroom, contributions because microgenetic designs facilitate our grasp regarding how instructional procedures actually exert their useful effects. We currently understand which stages and processes children go through when making transitions from ignorance of a domain to full understanding of a domain such as math (Seigler & Svetina, 2002; Seigler, 1995), science (Pine, Lufkin, & Messer, (2004)), and organizational strategies (Schlagmuller & Schneider, 2002). Implementing these findings in various applied contexts, while cognizant of the intervening elements within the learning process, is ostensibly the next pivotal step. Predicting if and when the benefits of teaching and interventions materialize can be confirmed through evidence derived from microgenetic studies. Such predictions, moreover, promise to be beneficial mechanisms for implementation into pedagogical practice.

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