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1 LOGIC: Introduction and Overview

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We would probably all agree that the main task of developmental psychology is to describe, predict, and explain change in human behavior and to uncover its determinants across the life span. Indeed, a look at the literature shows that it is full of empirical findings about age-related changes in behavioral, physical, cognitive, social, and personality variables. Thus, it would appear that the scientific study of human development is meeting its goal. However, this is only true at first glance.

A closer look at the literature provides the surprising information that more than 90% of psychological statements about developmental change are based on data that include no direct measures of change. For many developmental psychologists it is self-evident and unquestionable that one can infer laws of developmental change from observations of developmental differences between different age groups. Therefore, cross-sectional designs have become the rule, and longitudinal studies the exception.

From a theoretical point of view, taking mean age differences as indicators of individual change is a reasonable and valid research strategy, if – but only if – the developmental phenomena are universal; that is, if the laws that govern these phenomena are valid for all normal members of the human species. To be sure, for many aspects of human development, such a strong assumption may not pose any problems.

However, there is one risk and there are several disadvantages associated with this dominant mainstream position. The risk is that the one dominant methodological orientation and the one dominant theoretical perspective legitimize each other, which serves to immunize the theory against data that would support other possible perspectives. In addition to this fundamental problem, there are several obvious disadvantages to the exclusive use of cross-sectional methodology. These include its relative inability to describe individual growth functions; to identify individual patterns of change; and to describe, predict, or explain interindividual differences in intraindividual change.

In the following chapters of this volume, we concentrate on only one issue – that of interindividual differences in human development. A cross-sectional orientation

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typically reduces interindividual differences (both in how they are defined and how they are analyzed) to variations in the speed with which universal, age-related sequences develop.

Since the time of Albert Binet at the beginning of the twentieth century, it has been popular to predict subsequent development from early differences in developmental rate. These predictions are very often based on the implicit assumptions (a) that interindividual differences in the rate of development are, at least in some cognitive domains, stable over time and (b) that there is substantial correlation between the rate of development in a particular competence and the asymptotic level of that competence that can be attained. This is the primary theoretical and empirical basis of much prognosis within the psychometric approach to development. In the last 80 years or so there have been hundreds, maybe thousands of papers supporting or criticizing this view. However, continuing the discussion on the pros and cons of this approach is not our purpose in this volume.

Rather, we simply want to make the point that it seems both desirable and necessary to study interindividual differences in intraindividual change within a broader framework of reference and with more adequate methodologies. Longitudinal research designs of course meet some of the criteria for studying individual differences.

In spite of the many pragmatic, theoretical, methodological, and statistical problems with longitudinal studies, there is agreement that only this type of research design offers an opportunity to describe and analyze individual differences and to identify patterns of causes for their genesis and for the stability or variability of such differences.

The term *longitudinal design* refers, of course, to an omnibus concept that includes a large variety of empirical designs that show just one common feature (repeated measures of the same entity) and that differs in many ways, for example, in sample size (from single case studies to broadband panel designs including thousands of participants), in time-span (short-term and long-term studies), in the density of measurement points (many observations a day to a few observations over a 30- to-40-year span), in the number of variables (from one variable to hundreds of variables), and in the rigidity or openness of the particular design (in goals, instruments, time intervals, and so on).

Because there is no standard methodological instruction for longitudinal designs, planning a longitudinal study requires many explicit decisions, and the design that is developed depends, among other things, on the preferred theoretical framework, the aims of the investigation, and the opportunities and constraints afforded by the empirical data collection.

Basic Assumptions, Constraints, and General Aims of LOGIC

When the staff members of the developmental unit at the newly founded Max Planck Institute for Psychological Research started to think about a longitudinal project on

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child development in 1982, our first task was to consider those decisions necessary for designing a longitudinal study (LOGIC).[1]

Although the fields of research experience varied among the individual scientists in our group (e.g., cognitive development, memory, motivation, personality, social development, and moral judgment), we all shared an interest in knowing more about the genesis and course of individual differences in cognitive and personality development. This focus, rather unpopular and widely ignored in mainstream developmental psychology, arose from a sense of discomfort with the current state of theoretical thinking in the field. The value of the universal approach is that it offers an opportunity to describe behavioral development as a sequence of changes from the immature state of the infant to the species-specific level of the mature adult. To quote John Flavell's (1970) strong definition of development, "It is the underlying presence of a biological growth process that lends to childhood changes their inevitability, magnitude, directionality, within-species uniformity, and irreversibility" (Flavell, p. 248).

However, this perspective is only one side of the coin. To avoid misunderstandings, let us be clear that we agree that this side is necessary – one side of a coin cannot exist without the other. A look at the other side of the coin, however, reveals not the homogeneity of adult behavior but the obvious, huge, and overwhelming differences among adults. How do these differences emerge? What are early indicators of such differences? How stable are individual differences in various domains over time? What are the prospects for long-term prediction of individual differences in cognitive and personality development?

In our early discussions, we reached a decision to study several aspects of development, with a strong focus on the genesis of individual differences. In addition, we also agreed on the following points, derived not from a unified theoretical position, but more as the pragmatic result of combining several specific research orientations in various developmental domains:

1. We chose early and middle childhood as the age group to study. We decided to start with 3- to 4-year-old children just after they had entered preschool. From the very beginning of the study, we planned to observe the individual children at regular time intervals for at least 9 years, or until the average beginning of puberty. Indeed, this is what we did.
2. To study interindividual differences in intraindividual development across a variety of cognitive and personality domains, we followed the research interests of the scientific members in our team. Following this rule, we concentrated our efforts in cognitive development on
   - memory development (M. Knopf, W. Schneider, B. Sodian, G. Strube, and A. Weber) and
   - development of thinking (M. Bullock, H. Wimmer, J. Perner, B. Sodian, and A. Ziegler).

   Because some members of the research group were very much interested in

[1] LOGIC = Longitudinal Study on the Genesis of Individual Competencies (Longitudinalstudie zur Genese individueller Kompetenzen).

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connecting developmental and educational issues we also focused on some domain-specific skills from the elementary school curriculum:

- development and acquisition of arithmetic skills and mathematical understanding (E. Stern);
- acquisition of reading and spelling skills (W. Schneider, J. Näslund); and
- development of analytical reasoning in the science domain (M. Bullock).

Regarding the areas of personality and social development we focused on

- learning and achievement related behavior, motives, attitudes, and self concepts (A. Helmke);
- development of social competencies and inhibition (J. Asendorpf and M. van Aken);
- development of moral judgment, motivation, and behavior (G. Nunner-Winkler); and
- individual differences in selected personality characteristics (J. Asendorpf and M. van Aken).

To study such a variety of developmental domains we did not focus on a common, general theoretical orientation, but rather we explored domain-specific models, guiding questions, and research strategies – each with the common focus on individual differences.

To be able to provide a normative description of the sample, to make comparisons between the LOGIC data and other longitudinal data sets, and to have a common standardized set of reference variables within the LOGIC project available, we administered several selected standardized and widely used instruments at regular time intervals or at critical points of development. These instruments included

- measures of intelligence
- measures of social cognition
- assessments using Piagetian type tasks
- measures of school readiness in the preschool years
- measures of attention
- measures of motor skills

From this brief overview of the guiding principles and concrete decisions about the goals and topics of the project it should be clear that LOGIC was and is not a rigid fixed study with a set of invariant instruments but is more a variable and flexible longitudinal investigation that allowed some decisional options during the course of the study – all in all a procedure with some advantages and, of course, some disadvantages.

3. LOGIC is more or less – in our belief more than less – a descriptive study. The main goal was to describe the genesis and the stability and variability of individual differences in development and not to identify or even to analyze the causes of such developmental differences. In addition, there was neither a strong nor a systematic effort to gather data describing the social environment of the children, the living situation of their parents and siblings, or the educational atmosphere at home. We came to these decisions for two reasons: First, it seemed impossible to separate genetic and environmental factors in family effects on child development (without the frame of twin and adoption studies). Second, we assumed that descriptive models for individual differences are a necessary precondition for analyzing the causes of such differences. The lack of such models has perhaps been one main reason for the failure to integrate developmental and socialization research in the past. Thus, we decided not to attempt to take the attractive second step of looking at social–environmental causes before completing the necessary first step of describing individual differences in developmental sequences.
4. Nevertheless, looking for causal explanations is too strong a scientific temptation to ignore this second step completely. We used the fact that parents of elementary school

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children in Germany do not have the opportunity to freely choose their child's classroom or teacher. As a consequence, the variation in school environments (teacher personality and quality of instruction) is not confounded with genetic and environmental conditions in the family. Thus, to look at effects of school environment, we decided to supplement the individual-centered LOGIC study with a classroom-centered school project, the so-called SCHOLASTIC study.[2]

It was possible to observe more than half of the LOGIC sample together with their classmates in 54 classrooms (a total of more than 1,200 participants) during the 4 years of elementary school. We were able to observe, test, and interview these students five to nine times a year under regular classroom conditions. This design gave us the opportunity (a) to analyze the SCHOLASTIC data for the entire SCHOLASTIC sample and (b) to combine the data sets from the SCHOLASTIC and LOGIC projects for the overlapping sample to study the impact of classroom differences on individual development and on the genesis of interindividual differences.

LOGIC Sample

The sample size of a longitudinal study is always a compromise between scientific needs and pragmatic restrictions. After discussing the goals and strategies of the project and calculating the manpower necessary for a long time period, we came to the conclusion that 180 participants would be the minimal size of the sample – not only in the first but also in the expected last wave of the study. We were able to meet this criterion. Table 1 shows the original sample and changes over the time of the study.

Four points are of special interest from Table 1. First, finding enough participants for the LOGIC study was not an easy task. We decided that the sample should consist of children between the ages of 3 and 4, with German as their first language. Another decision was that the participant pool should consist only of children who enrolled in one of 20 carefully selected preschools in the fall of 1984. These preschools were in central Munich and in a suburban area; had a representative distribution of people with high, moderate, and low socioeconomic status (SES); had approval to participate in the study from the relevant authorities; and met our criterion of convenience for doing the empirical work. It was finally possible to recruit the initial sample of 205 children with full permission of their parents to participate in the study.

After having 13 children drop out in Wave 1, we included 25 additional children in the sample in Wave 2 to ensure that the longitudinal sample would not be reduced below our criterion level over the long run. There were no age differences between the new subsample and the original sample (but of course the 25 participants were tested in the second wave for the first time).

The ages of the original sample ranged from 3.4 to 4.7 years, with a mean of 4.0 years. Table 2 shows the distribution of SES of the parents – defined by father's occupational status. This distribution of SES seems representative and, in contrast

[2] SCHOLASTIC = School Learning and Socialization of Talents, Interests, and Individual Competencies (Schulorganisierte Lernangebote und Sozialisation von Talenten, Interessen und Kompetenzen).

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Table 1. *Original LOGIC Study Sample and Changes in the Sample Over Time*

	Wave								
Sample	1 84/85	2 85/86	3 86/87	4 87/88	5 88/89	6 89/90	7 90/91	8 91/92	9 92/93
n	205	217	213	204	200	195	194	189	186
Increase	0	25	0	0	0	0	0	0	0
Decrease	0	13	4	9	4	5	1	5	3
Boys	105	113	111	105	104	101	101	100	99
Girls	100	104	102	99	96	94	93	89	87

Table 2. *Distribution of Socioeconomic Status (SES) of the Participants in the LOGIC Study*

SES	*n*	%
Low	$n = 57$	28
Average	$n = 127$	63
High	$n = 19$	9

to many other longitudinal studies, provides no indication that the sample is biased with more participants from higher SES families.

The second point to note in Table 1 is that the dropout rate from Wave 2 to 9 was very low (31 participants altogether, from a sample of $N = 217$). Considerable efforts were made to keep the children and parents motivated to participate in the three testing sessions each year. These efforts included steady contact with the parents in the form of letters and evening presentations to discuss the study (without any information about individual children). Dropout was caused primarily by the families' moving away from the area, although in a few cases the child or the parents refused to participate further in the study. The credit for this low dropout rate goes especially to the research assistants.

To check for continued representativeness we compared the dropout sample and the remaining sample for sex, SES, and intelligence. No significant differences could be found.

Third, because of the large number of observations (27 across the 9 years) and the huge number of variables measured, the number of children with complete data sets is relatively small. As a consequence, statistical analyses are based on different numbers of participants. Because the principle of listwise deletion would have reduced the sample size too much, the principle of pairwise deletion was used in most cases to allow us to retain as much information as possible.

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Table 3. *Intelligence Scores for Girls and Boys*

Wave	IQ verbal boys	IQ verbal girls	IQ nonverbal boys	IQ nonverbal girls	Total IQ boys	Total IQ girls
Wave 1[a]	106.33	106.91				
Wave 2[a]	107.98	105.96	104.00	106.56	105.99	106.26
Wave 4[b]	102.21	98.72				
Wave 6[b]	109.06	105.22	98.74	96.43	104.45	100.51
Wave 9[b]	112.76	104.66				

[a]Indicates the Wechsler Preschool and Primary Scale of Intelligence was used to measure intelligence.
[b]Indicates the Wechsler Intelligence Scale for Children was used to measure intelligence.

Fourth, over the course of some longitudinal studies, the sample seems to become a unique population, perhaps as a result of repeated testing with its resulting opportunities for coaching, training, or feedback effects. To check for such effects, we compared the verbal IQ, the nonverbal IQ, and the overall IQ for boys, girls, and the whole sample across different waves. Table 3 shows this information. Analyses of variance with these data sets did reveal a significant main effect of time and a significant interaction between time and sex. However, despite these rather small changes in intelligence measures, we can state with some confidence that our sample did not develop into a nonrepresentative population over the course of the LOGIC study.

LOGIC Design

Figure 1 shows the sample and the course of the LOGIC study, as well as an overview of the sample and the course of the SCHOLASTIC study.

As Figure 1 illustrates, the LOGIC study lasted for more than 9 years with three measurement points per year (October–December, January–March, and April–June). Each measurement point provided the opportunity to observe, test, and interview each individual child for more than 2 hours. The children were tested individually, except in some cases in which groups of two or more children were observed to assess indicators of social behavior.

In September 1987, most children in the sample entered the first grade of elementary school. As mentioned earlier, from this point in time a subsample of 108 children from the LOGIC group together with more than 1,000 classmates in 54 classrooms participated in the SCHOLASTIC project.

In this project, testing took place during regular school hours and included five to nine measurement sessions per year. The measurements comprised tests of fluid intelligence, the solution of mathematic word problems and math tasks requiring arithmetic skills, reading comprehension, spelling, and analytic reasoning in the science domain. School grades for each of these topics were also available. In addition,

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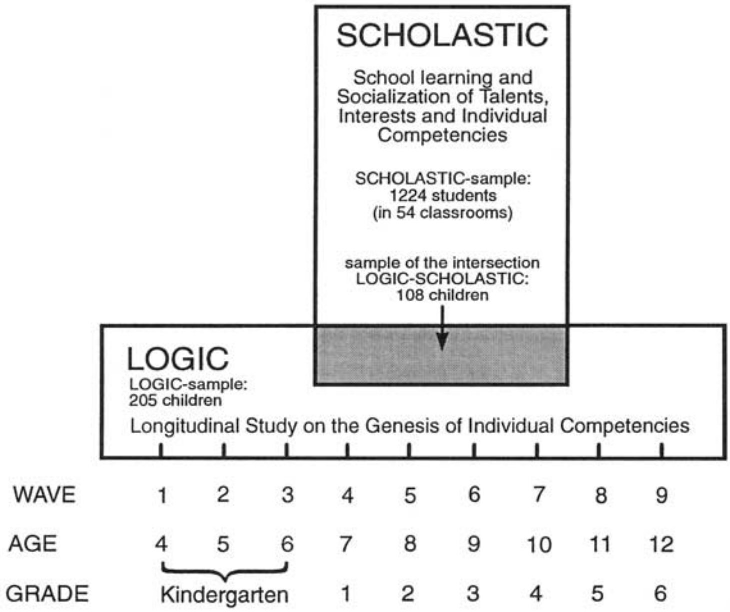

Figure 1. Samples and time course of the longitudinal LOGIC and SCHOLASTIC studies.

information concerning various aspects of the motivation to learn, achievement motivation, and the academic self-concept was gathered by questionnaires; children's attentive behavior in the classroom during instruction was measured with a low-inference, time-sampling observation instrument. These data were complemented by regular ratings by observers in the classroom concerning teaching and teacher behavior, allowing the construction of a large number of high-inference scales addressing different aspects of teaching and management quality.

In the following chapters we report on selected results from the main topics of the LOGIC study; in one chapter we use data from the SCHOLASTIC study. However, the findings represent only a small part of the results from the LOGIC study. A longitudinal investigation is like a machine for generating a huge amount of data and provides the opportunity not only for one comprehensive presentation but for many special presentations and publications. It will take us years to exploit the whole data set. In taking a bottom-up perspective, we are trying to go beyond the domain-specific type of analyses and are looking for more general developmental regularities.

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2 Development of Intelligence and Thinking

Wolfgang Schneider, Josef Perner, Merry Bullock, Jan Stefanek, and Albert Ziegler

This chapter is concerned with developmental changes in aspects of intelligence and thinking assessed in the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC). Although the majority of measures used in the study stemmed from a psychometric approach, several experimental procedures assessed constructs typical of a cognitive developmental approach. One purpose of the present analysis is to relate cognitive developmental tasks assessing general developmental milestones with psychometric intelligence at different time points to explore the interrelationships among these variables for different ages. Because of time constraints, the design used to investigate this issue was not as systematic as that of many longitudinal studies focusing solely on intellectual development (e.g., Schaie 1994). Before we present the measures and the results in more detail, we provide a short overview of the existing literature on developmental changes in intelligence and thinking.

The Starting Point: Psychometric Perspectives on the Development of Intellectual Ability

The study of the development of mental abilities has a long tradition in the field of psychology. Since the 1880s, numerous tests of psychometric intelligence have been used worldwide to explore children's cognitive abilities and to characterize the structure of these abilities. From the very beginning, the definition of the term *intelligence* aroused much controversy, because there were diverse views of the structure and organization of intelligence. This divergence was first illustrated in 1921 when the editors of *Journal of Educational Psychology* collected definitions of intelligence from several experts in the field and was replicated again in later, similar attempts where the diversity among experts' views was striking (Sternberg and Detterman 1986; cf. Berg 1992). However, despite problems in agreeing on a narrow definition of intelligence, most researchers dedicated to the psychometric approach agree that the nature of intelligence and intellectual development can be fruitfully studied by examining individual differences in performance on tests of mental abilities (cf. Kail and Pellegrino 1985; Siegler and Richards 1982; Sternberg and Powell 1983). From

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this perspective, the primary developmental interest has been in assessing the stability of individual differences over time.

It is, however, important to note that the study of individual differences is only one aspect of the overall picture of the development of psychometric intellectual ability (cf. Gardner and Clark 1992). Focusing exclusively on individual differences and their stability overlooks the fact that change or stability in individual differences (indicated by correlations across various intelligence tests) is logically independent of growth in the average level of mental ability (cf. McCall 1981; Schneider 1989). Ignoring this difference can yield misleading conclusions. One famous example concerns Bloom's (1964) claim that 50% of an individual's adult intelligence is already developed by the age of 4. This claim was based on the finding from previous studies that the correlations among IQs assessed at age 4 and at age 18 average around .7, which means that they share about 50% variance. The reason that this conclusion is misleading is that Bloom's claim is based solely on the stability of individual differences and not on the absolute level of mental abilities. Undoubtedly, a 4-year-old's performance level is far less than 50% of the 18-year-old's.

Both individual differences and overall growth were assessed in several famous longitudinal studies conducted during the first half of this century at different places in the United States (for overviews, see Bayley 1970; Gardner and Clark 1992; Goodenough 1946). Although most of these studies focused on individual difference questions such as stability over time, some studies also explored the question of developmental changes in mental growth rates. Typically, participants in these studies were recruited at an early age (during infancy or the preschool years) and followed until adolescence or adulthood.

Findings regarding the stability issue can be summarized as follows:

1. Infant tests of intelligence do not predict later intelligence levels (cf. Bayley 1949, 1970; McCall, Hogarty and Hurlburt 1972). McCall et al. pointed out that the lack of a correlation is not due to poor infant test reliability. Rather, they give the plausible explanation that the competencies measured in infancy are different from those measured in the preschool years and later.
2. Later intelligence levels can be predicted with sufficient accuracy from age 3 on (cf. Bayley 1949; Honzik, MacFarlane, and Allen 1948; Sontag, Baker, and Nelson 1958). For example, stable patterns were found in an 11-year follow-up study by Yule, Gold, and Busch (1982), who tested a sample of 85 children on the Wechsler Preschool and Primary Scale of Intelligence (WPPSI, Eggert 1978) at about 5 years and then on the Wechsler Intelligence Scale for Children (WISC, Tewes 1983) at about 16 years. Long-term predictive validity of the WPPSI was found to be high: The intercorrelation between the full-scale IQs on the two tests was .86. Generally, correlations between IQ scores across different ages show the familiar simplex pattern, with values increasing as the intervals between tests decrease. For instance, Hindley and Owen (1978) reported a test–retest correlation of .53 for IQ scores assessed at the ages of 3 and 17 years, compared with .74 for scores assessed at ages 8 and 17 and .87 for scores assessed at ages 14 and 17.

Although most longitudinal studies on intellectual development showed high temporal stability between the preschool period and adolescence, they did not support the notion of a "constant IQ." Most longitudinal researchers noted considerable

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