

Reprint of:

Kruse, A., Lindenberger, U., & Baltes, P. B. (1993)

Longitudinal research on human aging:
The power of combining real-time,
microgenetic, and simulation approaches
(pp. 153-193)

In: D. Magnusson & P. Casaer (Eds.), Longitudinal research on individual development. New York: Cambridge University Press.

8 Longitudinal research on human aging: the power of combining real-time, microgenetic, and simulation approaches

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INTRODUCTION

In the present chapter, we proceed from the premise that the study of ontogenesis requires a methodology that is inherently focused on the study of intra-individual change and inter-individual differences in intra-individual change (Baltes, P. B., Reese, & Nesselroade, 1977). We argue, however, that real-time longitudinal studies with single cohorts is not enough. Rather, as outlined already in the 1960s and 1970s in the field of life-span development and aging (Baltes, P. B., 1968; Labouvie, 1980; Nesselroade & Reese, 1973; Schaie, 1965, 1979), the final power of longitudinal research rests in its creative use as a rather heterogeneous category of research strategies including microgenetic and simulation approaches (Baltes, P. B. & Goulet, 1971; Baltes, P. B. et al., 1977; Siegler & Crowley, 1991).

The call for a broad range of longitudinal methods is based on the assumption that behavioural development is the result of a complex, multilevel interaction of factors and mechanisms. It is unlikely that this nexus of biologically, socially and societally determined influences on development can be unravelled by longitudinal designs which are essentially descriptive or quasi-experimental in nature. For example, life-span theory suggests that development and aging are jointly determined by age-graded, history-graded, and non-normative systems of influence (Baltes, P. B., 1987; Baltes, Cornelius, & Nesselroade, 1979; Dannefer, 1987; Elder, 1986; Featherman, 1983; Kruse, 1992; Mayer, 1990). Some processes may exhibit a high correlation with age, whereas others are a reflection of historical change. In addition, some events or changes do not occur universally for all people. These non-normative events may have cumulative

effects and may lead to an increase in inter-individual variability with age. Developmental trajectories of individuals of a given cohort always represent specific combinations of age-graded, history-graded, and non-normative influences. Without additional assumptions or data, one does not know whether these trajectories are generalizable to other cohorts. Moreover, without decomposition of age and cohort trends into constituent processes – for example, by intensive single-subject studies or by additional experimentation in the laboratory – it is impossible to identify the operative forces and mechanisms with a sufficient degree of precision and certainty. Thus, the analysis of longitudinal change processes requires a coalition of methodologies to estimate the possible range of intra-individual change trajectories, and to identify possible antecedents of age-related change.

A TAXONOMY OF LONGITUDINAL RESEARCH METHODS

We propose that longitudinal methods fall into three basic categories: real-time, microgenetic, and simulation studies (Baltes, P. B. et al., 1979; Baltes, P. B. & Nesselroade, 1979; cf. Rudinger & Wood, 1990). With respect to real-time studies, a distinction can be made between single-cohort and multiple-cohort designs. The classical one-cohort real-time longitudinal study is well suited for the description of developmental processes, especially if the theory assumes that the processes to be studied are relatively invariant across cultures and historical time. The best examples for such processes are normally found in early childhood (e.g. sensorimotor development), and presumably are under relatively direct genetic control. However, relatively invariant developmental processes are also obtained when society- and socialization-based influences are well standardized as to age and have become stabilized over historical time.

Multiple-cohort studies, especially if they implement a full-blown cohort-sequential design (Baltes, 1968; Baltes et al., 1977; Schaie, 1965), serve to estimate the relative importance of historical change processes for developmental change functions across a given historical period. In contrast to single-cohort studies, cohort-sequential studies are well suited to explore the historical relativity (i.e. context dependence) of developmental change functions (for an example, see Schaie, 1990a). The extent and direction of historical effects alone adds to our knowledge about the possible range of development, and may guide our subsequent search for causal mechanisms.

The main disadvantage of both single- and multiple-cohort real-time longitudinal studies is their relative lack of explanatory power. Despite recent advances in statistical methodology (Collins & Horn, 1991; Magnusson & Bergman, 1990), especially in time series analysis (Gollob & Reichardt, 1991; Jones, 1991) and structural modelling (Muthén, 1991), causal inferences are generally difficult to draw on the basis of real-time longitudinal data, mainly because we lack experimental control over antecedent conditions (cf. Rutter, 1988b).

Therefore, real-time longitudinal methods need to be combined with methods that allow for a better control over antecedent conditions if the goal is to test specific hypotheses regarding variables producing age-related change. We suggest two such methods, microgenetic intervention and developmental simulation.

The microgenetic method (Siegler & Crowley, 1991) is based on the assumption that there are important commonalities underlying changes that occur on different time scales (Werner, 1948). Therefore, the careful analysis of time-compressed change functions may lead to a better understanding of medium- and long-term developmental changes. Put differently, microgenetic intervention may help to explain age-related change functions by a systematic analysis of age differences in the quantity or quality of intra-individual change processes. Microgenetic work often involves the observation of individual subjects, a high density of observations, and intensive data analysis to infer interindividual differences in intra-individual change (Baltes, P. B. et al., 1977; Siegler & Crowley, 1991; cf. Werner, 1948). Good examples for this type of design are cognitive training studies which provide optimal learning conditions to identify age differences in developmental reserve capacity and to explore the boundary conditions of what is possible in principle (Baltes, P. B. & Kliegl, 1992; Baltes, P. B. & Lindenberger, 1988; Kliegl & Baltes, 1987a, 1987b, Willis, 1987).

Developmental simulation refers to the theory-guided arrangement of experimental conditions that simulate or mimick age-related change for the purpose of explanatory decomposition of age trends observed in real-time studies (Baltes & Goulet, 1971). As a research strategy, the simulation of developmental processes generally involves five steps (cf. Baltes et al., 1977): 1) definition of the developmental phenomenon (i.e. the age-related change function) to be explained; 2) formulation of a set of hypotheses about age-associated variables that might produce the phenomenon; 3) experimental manipulation of these variables; 4) test of the data obtained through simulation against the target phenomenon (isomorphy check); 5) examination of external validity as well as search for alternative causal mechanisms.

Recent research examples of developmental simulation include mathematical models of age differences in skilled memory performance (Kliegl & Lindenberger, 1988; Kliegl, 1992), connectionist models of both stage-like (McClelland, 1989) and more continuous (Siegler, 1988; Hoyer & Hannon, in press) age changes in cognitive functioning, and the simulation of aging-related memory deficits in young adults through the experimental impairment of attentional processing (Nilsson, Bäckman & Karlsson, 1989). An early life-span example is Sjostrom and Pollack's (1971) attempt to understand the differential age trajectories of two types of visual illusions by manipulation of sensory input in different age groups and by application of lenses mimicking age changes in visual acuity.

The combined use of real-time, microgenetic, and simulation approaches is

not always possible, mainly because certain developmental processes are difficult to time-compress or simulate in the laboratory. Some developmental factors, some age-associated conditions may not be decomposable into shorter time spans. Despite these difficulties, however, efforts at microgenetic and simulation research are mandatory to achieve a complete understanding of the nature of human development, even if they 'only' demonstrate that a full understanding of the nexus of causal factors and mechanisms involved is not possible.

In the following, to illustrate the power of the expanded view of longitudinal research, we will discuss five prominent issues in the psychological study of human aging: representativeness, inter-individual variability, investigations into limits of functioning (plasticity), the distinction between normal and pathological aging, and the search for mechanisms of successful aging. We do not intend to provide a comprehensive review of any of these issues. Rather, we would like to argue in each case that the acquisition of new knowledge is critically contingent not only upon real-time longitudinal research but also upon the combination of different types of longitudinal methodology. Typical examples from recent research will be used to illustrate this claim.

REPRESENTATIVENESS IN AGING RESEARCH

Representativeness is a generic term referring to individuals, variables, and measurements (Magnusson & Bergman, 1990). In the following, we concentrate our discussion to two threats to representativeness, selective survival and selective sampling. As we would like to argue, problems related to these two issues are especially prominent in aging research. Their examination requires a longitudinal approach.

Selective survival

Chronological age is commonly seen as a marker variable for development, with the goal to replace it by more direct indicators of developmental change processes (Wohlwill, 1970). This also holds true for aging research. In addition, however, chronological age also functions as a marker variable for sample selection (Lawley, 1943-44). In modern Western societies, for instance, about 85% of a birth cohort are alive at age 60 (Dinkel, 1992; Putz & Schwarz, 1984). This percentage is reduced to about 5% at the age of 90. Given that the 5% still alive at age 90 are not randomly selected from the 85% alive at age 60, any direct comparison of 90-year olds with 60-year olds is difficult.

In the case of cross-sectional data, such a comparison will be biased because a highly select sample is compared against a less select sample. More importantly, however, the extent and the direction of the bias cannot be assessed by cross-sectional data because the bias can involve historical changes in the different birth cohorts making up the cross-sectional composition. In the case of real-time longitudinal data, assessment of age-related changes in the parent birth

cohorts are possible. However, the results are possibly cohort-specific and the final analyses are increasingly restricted to those individuals who lived long and, in addition, provided data on all measurement occasions (e.g. the biological and longitudinal study survivors). As a consequence, results can only be generalized to a rather small portion of the elderly population.

One way to tackle the problems involved in cross-sectional and real-time longitudinal comparisons of old and very old adults is to carefully analyse the reasons for the existence of selective survival (Manton & Woodbury, 1983; Powell et al., 1990; Siegler & Botwinick, 1979; Cooney, Schaie & Willis, 1988). In analogy to Wohlwill's (1970) line of reasoning, age as a selection variable has to be replaced by other variables that are more direct indicators of interindividual differences in mortality and morbidity (Manton & Woodbury, 1983; cf. Aitken, 1934).

Real-time longitudinal data may lead to a better understanding of selective survival if attempts are intensified to predict who drops out of a sample due to chronic illness and death and who does not. Recent advances in structural modelling techniques with non-random missing data (McArdle & Hamagami, 1991; McArdle et al., 1991; Rovine & Delancy, 1990; Rubin, 1991) may prove to be very useful in this regard. The theoretical rationale for dropout (i.e. selectivity) analyses would be to identify the ensemble of protective and risk factors which contribute to inter-individual differences in longevity. Thus, sample attrition due to selective survival may not be a cause for concern but an opportunity for gaining new insights about the relationship among mortality, morbidity, and age.

Another way to address the problem of selective survival is the increased use of methods with dense spacing of observations or observational formats that are event rather than time driven (Blossfeld, Hamerle & Mayer, 1989). In the extreme case, such a strategy amounts to what we have defined as a microgenetic approach. Especially in the case of very old age, where the average life expectancy is lower than, say, five years, it may be more meaningful to intensively study a small number of individuals over a relatively short period of time than to aim for the implementation of conventional real-time longitudinal designs with fixed intervals of observation.

Selective sampling of the universe of the aging population(s)

Human aging is not well described by a unitary age function that holds true across all individuals and domains; rather, it comprises a multitude of possible trajectories and profiles, both across individuals and domains of functioning (Baltes, 1991; Baltes & Baltes, 1990, 1992; Birren, 1988; Busse & Maddox, 1985; Lehr & Thomae, 1987; Schaie, 1989*b*; Svanborg, 1985; Thomae, 1976, 1983). In the following, we use the term 'patterns of aging' (Lawton, 1989; Thomae, 1979) to refer to the multi-dimensionality and multi-directionality of the aging

process, and to the fact that there is large inter-individual variability in the onset, rate, and direction of age changes.

Inter-individual differences in patterns of aging can be described in terms of differences in person-environment transactions (Lawton, 1989), person-situation interactions (Lerner, 1978; Magnusson, 1988; Magnusson & Endler, 1977; Thomae, 1988), or as the result of processes of social differentiation due for instance to gender, social class, or ethnicity (Dannefer, 1987; Featherman, 1983; Sørensen, Weinert & Sherrod, 1986). The notion of transaction or interaction refers to the fact that aging individuals continuously adapt to situational opportunities and demands that require physical, cognitive, and personality-related competence. At the same time, they also modify certain aspects of the environment by virtue of this competence. While this is true for all phases of the life-span (Lerner, 1978), the specific challenge of aging lies in the fact that the age-correlated power of biological and environmental influences wanes with age and that non-normative factors and individualized pathways become relatively more prominent. That this is so has evolutionary as well as ontogenetic reasons (Baltes & Baltes, 1992). From an evolutionary point of view, aging is a post-reproductive phenomenon and therefore less subject to genetic selection. From an ontogenetic point of view, there is a less developed (less standardized and optimized) culture of old age than is true for earlier periods of the life-span.

To examine a broad spectrum of aging patterns, longitudinal aging studies need to represent a great variety of different genetic and environmental conditions. In contrast to this proposition, most real-time longitudinal studies on aging tend to over-represent healthy individuals with middle or high socio-economic status and middle or high educational background. We do not know to what degree findings from these studies are generalizable to individuals who are living under less favourable or in diverse social conditions (e.g. race, ethnicity, etc).

The bias towards overrepresenting the well educated and the wealthy makes it difficult to evaluate the effects of adverse environmental conditions on the course of aging. It appears that restricted environments are often associated with a relatively high prevalence of pathology, and may lead to a reduction of inter-individual variability because skills and abilities are not activated. Still, individuals seem to be able to maintain subjective feelings of well-being under such conditions unless their physical and emotional resources are depleted (Kruse, 1992). Future longitudinal research on aging needs to undertake a special effort to encompass a broad range of environmental conditions. In particular, the drawing of truly representative samples and the oversampling of certain groups at risk for pathology may be necessary to allow for the systematic comparison of individual and environmental conditions over time. In this case as well, the use of single-subject, microgenetic, and simulation methods holds much promise. By such methods it is possible to specify and intensify particular constellations and reach beyond current reality. Lindenberger, Kliegl, and

Baltes (in press) demonstrated, for instance, how an expertise- and life-history guided selection of subjects (finding a small number of older persons with favourable dispositions for and practice in mental imagination) in combination with intensive memory training (based on strategies of mental imagination) produces new insights into the aging of memory.

INTER-INDIVIDUAL VARIABILITY

In the previous section, we suggested already that one of the major findings of gerontological research is the magnitude of inter-individual differences in functional status among elderly individuals. In contrast to initial assumptions about the uniformity of the aging process (Cowdry, 1939), there are 80-year olds who appear like 60-year olds and vice versa. This substantial inter-individual variability is found both for psychological and behavioural (Lehr & Thomae, 1987; Maddox, 1987; Nesselrode, 1990; Schaie, 1979; Svanborg, 1985) as well as for biomedical indicators (Costa & Andres, 1986; Rowe & Kahn, 1987). The demonstration of such variability, is based on longitudinal and cohort-sequential studies (e.g. Schaie, 1983, 1988, 1990*b*).

While the existence of a wide range of inter-individual variability in old age is an undisputed fact, the relative importance of possible causes for age-related changes in variability is less clear (cf. Holland & Rabbitt, 1991; Schaie et al., in press). Does inter-individual variability in old age reflect, for the most part, the existence of life-long individual differences that are relatively unaffected by aging-related processes? In this case, the basic picture would be one of continuity and stability, and inter-individual differences in intra-individual change, if they were present, would only work in the direction of enhancing already existing differences without altering the rank order of individuals. In the field of personality research, Costa and McCrae (1988) are strong proponents of this view.

However, the transition to late adulthood may also be accompanied by changes in the magnitude and/or stability of individual differences. Some factors may lead to an increase in inter-individual variability. For instance, individuals may differ in the onset and the rate of aging-related decrements in the efficiency of cognitive processing (Schaie, 1989*a*). In addition, differences in life-styles, past work experience, and genetic dispositions may exert a cumulative effect on individual differences in attitudes and behaviour (cf. Baltes, P. B. & Nesselrode, 1978). As a consequence, some, but not all individuals may evince growth in select areas of functioning such as self-related behaviour (Brandstädter & Baltes-Götz, 1990), wisdom-related knowledge (Baltes, P. B. & Smith, 1990), or professional expertise (Hoyer, 1985). Similarly, health decline will not affect all individuals at the same age and to the same extent.

On the other hand, inter-individual variability may decrease again as individuals approach the very end of their life-time, at least if we assume that the proximity to one's 'natural' death is associated with a lawful decline of bodily

functions (i.e. the 'terminal decline' hypothesis; cf. Riegel & Riegel, 1972). Thus, proximity to death, rather than advanced age per se, may reduce phenotypical diversity.

At present, the prediction of inter-individual differences in the onset and magnitude of late-life changes is hampered by a lack of knowledge about relevant antecedent conditions. Without a rather extensive set of a priori assumptions – which may have been obtained on the basis of results from previous longitudinal studies – cross-sectional studies are silent with respect to the mechanisms explaining the existence of functional variability within and across age-groups or cohorts. Therefore, a coalition between real-time, microgenetic, and simulation methods of longitudinal research is needed to adequately describe and explain the ensemble of causal mechanisms that determine the magnitude of inter-individual variability during the last third of the life span.

Nesselroade (1990), for instance, has shown that a major share of inter-individual variability is due to short-term fluctuations in functioning. He was able to make this case by intensive short-term observations and measurements of personality functioning over several months. Maciel, Heckhausen and Baltes (1992) argued that, to understand longitudinal stability of personality traits (Costa & McCrae, 1988), it is necessary to study the internal comparison standards that people use when responding in self-report questionnaires. Moreover, microgenetic studies provide insights into changes in variability under conditions that have a low likelihood of occurrence in present-day societies. For instance, they can provide optimal environmental conditions with respect to the acquisition of specific cognitive skills in order to test propositions about inter-individual variability in upper limits of functioning (i.e. developmental reserve capacity; Kliegl & Baltes, 1987a, 1987b). Finally, simulation approaches allow for the theory-guided mathematical modelling of age-related changes in inter-individual variability (see Baltes, P. B. & Nesselroade, 1978, for an example).

First example: interindividual variability in late-life cognitive functioning

Both the results of cohort-sequential and real-time longitudinal studies suggest that variability in cognitive functioning increases, rather than decreases, during the transition from middle age to late adulthood (Cunningham & Birren, 1980; Hertzog & Schaie, 1986, 1988). In other words, growing into old age appears to be a source of inter-individual differences in cognitive functioning.

Data from the Seattle Cohort-Sequential Longitudinal Study may serve as an illustration. First, this study revealed major cohort effects in level and direction of psychological functioning (Schaie, 1979, 1983). Such cohort effects suggest that the level and form of cognitive aging functions are much influenced by experience.

Secondly, the Seattle Study informs us – especially because of its multiple-

cohort design – about cohort-generalizable age trends. In a comprehensive re-analysis of this data set, Hertzog and Schaie (1986, 1988; see also Schaie, 1989a) reported that most individuals between the age of 55 and 70 made a transition from a stability to a decline pattern in general intelligence as measured by subtests of the Thurstone Primary Mental Abilities (PMA; Thurstone & Thurstone, 1949). Thus, beyond age 60 or so decline in cognitive functioning was relatively normative, but individuals differed in the age of onset of this decline. Despite the concomitant increase in inter-individual variability with age, individual differences in general intelligence were highly stable, with correlations between adjacent 7-year intervals in the 90s. In other words, the amount of crossover of individual aging trajectories was small when measured against the variability of the sample.

These results seem to suggest that decline in cognitive functioning is quite normative, that the stability of inter-individual differences is quite high, and that the magnitude of inter-individual differences in cognitive functioning increases, rather than decreases in late adulthood. However, a few notes of caution are in order. First, one has to keep in mind that even stabilities in the nineties allow for sizeable inter-individual differences in intra-individual change. Fig. 8.1, taken from the same data set, illustrates this claim. By constructing confidence bands of 2.5 SEM (standard errors of measurement) around individual data points, Schaie (1988, 1990b) reported the proportion of individuals evincing a pattern of gain, stability, or loss in intelligence test scores as they traversed the age-span from 60 to 80. Clearly, not all individuals underwent decline, and a substantial minority increased their test scores according to this criterion.

Second, as Hertzog & Schaie (1986; see also Cooney, Schaie & Willis, 1988) pointed out themselves, longitudinal aging samples are generally influenced by a substantial degree of experimental mortality (attrition). It is very likely that individuals suffering a major loss in functional capacity due to severe illness or terminal decline dropped out of the longitudinal sample. Thus, the degree of stability in inter-individual differences observed in the survivors probably is an over-estimation of the stability in the population. As argued in more detail above, careful analyses of sample representativeness, sample selectivity, and longitudinal attrition (Baltes, P. B. et al., 1977) are needed to estimate the magnitude of this effect (cf. Gruenberg, 1986).

Finally, we cannot exclude the possibility that inter-individual variability in cognitive functioning decreases in very old individuals because the data set is restricted, as is true for most studies, to the young-old segment of the elderly population; only few subjects in the sample are above 80 years of age. In young-old populations, the continued existence of high inter-individual variability may be due to the fact that individuals still differ considerably in their closeness to death. *Inter-individual variability may be less pronounced when the focus is on old-old rather than young-old individuals, or when courses of aging are plotted backward from death rather than forward from birth* (cf. Kleemeier, 1962).

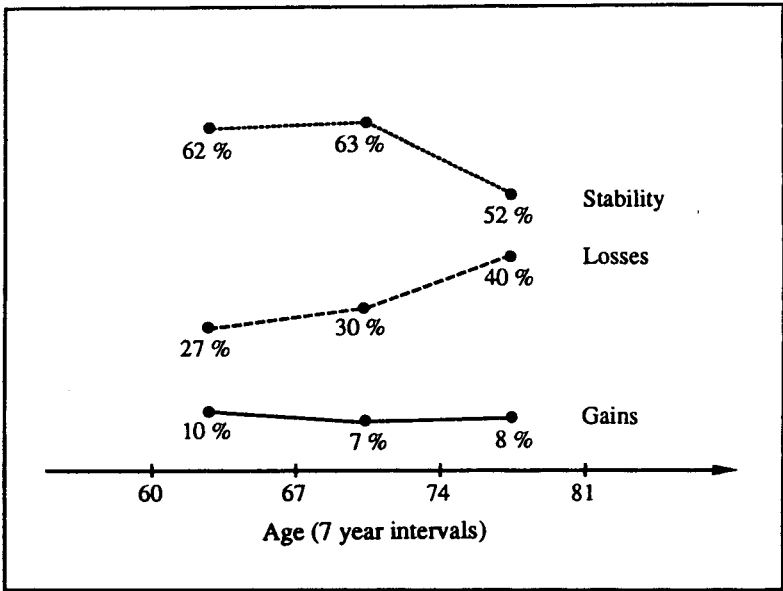


Fig. 8.1. Percentage of individuals showing stability, losses, or gains in intelligence. (Reanalysed and based on Schaie, 1988, 1990b.)

For this reason, future longitudinal research on aging should be expanded into very old age. Given the high mortality rate in the very old population, this may require deviations from canonical longitudinal methodology. For instance, it may be useful to adjust the time period between adjacent measurement points as a function of age-graded mortality risks, or to closely follow a relatively small member of very old subjects over time (cf. Jones & Nesselrode, 1990). Moreover, death records should be used whenever possible to reorganize existing as well as new data sets in terms of distance from death.

Real-time longitudinal (especially cohort-sequential) research on cognitive aging, then, has provided us with important information on inter-individual variability. This information, however, is largely descriptive. Cognitive training studies, in combination with real-time studies (Schaie & Willis, 1986; Willis, 1991) or as separate research programmes (Baltes, P. B. & Lindenberger, 1988; Baltes, B. B. & Willis, 1982; Kliegl, 1992; Kliegl & Baltes, 1987*a,b*; Willis, 1987) have supplemented this descriptive information. To what degree are the age functions observed modifiable? To what degree is it possible to produce major changes in rank order by exposing different individuals to differing learning conditions? To what extent can the biologically based decline of cognitive aging be overcome, reversed, or slowed down?

These are the kinds of questions that require the enrichment of real-time longitudinal data with microgenetic and developmental simulation work. We

know from training studies in the cognitive domain that a few sessions of instruction and training elevate the performance level of healthy older adults up to two standard deviations above their untrained peers (Baltes & Lindenberger, 1988; Kliegl, Smith & Baltes, 1989). Such results underscore the relevance of environmental conditions in the production of different aging outcomes, and shed new light on the interpretation of variability estimates based on data from real-time longitudinal studies. Furthermore, based on intensive memory training studies (Baltes, P. B. & Kliegl, 1992), we now know that there are definite limits that cannot be overcome, although real-time longitudinal intervention work (necessarily of less intensity) such as that by Schaie and Willis (1986) suggested otherwise. And, to give a final example, we now know through cognitive training research of the microgenetic kind that some subgroups of the elderly (such as persons identified as at risk for Alzheimer dementia) benefit much less from training or may not benefit at all (Baltes, M. M., Kühl & Sowarka, in press). Again, based on simple real-time longitudinal assessment, this information would not be available and real-time age trends would be misinterpreted.

Second example: trait- vs. process-oriented approaches to late-life personality

A central theme of life-span research on personality is the question to what extent inter-individual differences in personality and self-related behaviour are affected by aging (Asendorpf & Weinert, 1990; Bengtson, Reedy & Gordon, 1985; Block, 1981; Brim & Kagan, 1980; Costa & McCrae, 1988; Field & Millsap, 1991; Filipp & Klauer, 1986; Magnusson, 1990; Magnusson & Endler, 1977; Munnichs et al., 1985; Shanan, 1991; Thomae, 1988). Two different views on the issue can be set apart. Trait-oriented approaches (Costa & McCrae, 1988) tend to emphasize continuity of inter-individual differences in personality dimensions, whereas process-oriented approaches (Filipp & Klauer, 1986; Magnusson, 1990) emphasize transformations in coping styles, self-related behaviours, and belief systems as a function of age-graded changes in situational demands. In the following, using longitudinal evidence, we will elaborate on this difference and suggest possible directions for future research.

Based on the assumption of a partly pre-programmed personality structure evolving early in life, many trait theorists posit that inter-individual differences in personality are stable throughout the entire adult life-span, including old age. The results of several real-time longitudinal studies, such as the Baltimore Study (Costa, McCrae & Arenberg, 1983; Costa & McCrae, 1988) and the Normative Aging Study (Costa et al., 1987; Spiro, et al., 1990), seem to support this view. For instance, Costa and McCrae (1988) reported stable pattern of inter-individual differences and sample means in the 'Big Five' (Digman, 1989) personality dimensions over a six-year period.

A recent cohort-sequential study (Schaie, Dutta & Willis, 1991) on the level

of functioning focusing on the trait of flexibility versus rigidity is equally consistent with the idea of a basic continuity in personality traits during adulthood. The authors found that the negative correlation between age and flexibility commonly observed in cross-sectional research is probably due, for the most part, to cohort effects. After accounting for cohort effects in their data, the authors still observed a decrease in flexibility after about age 60. However, this decrease was smaller than the corresponding difference between young and old adults in cross-sectional comparisons. The authors argue that the cohort effect may reflect a secular trend due to historical changes on a third variable such as education. Given that flexibility predicts the ability to profit from experience, these data provide an empirical basis for the optimistic assumption that future cohorts of elderly individuals will be increasingly able to maintain and develop their intellectual, self-related, and social potential.

On the other hand, proponents of a more process-oriented view on personality and development (Magnusson, 1990; Magnusson & Endler, 1977; Pervin, 1985; Thomae, 1988) argue that certain personality characteristics and self-related behaviours (e.g. coping styles, control beliefs) vary as a function of situational demands. As a consequence, age-graded changes in these aspects of personality are expected to the extent that there is an age-graded change in the demand characteristics of the environment. Such changes would not necessarily lead to a reorganization of personality as it has evolved during the life-course; rather, the consequences would be more or less domain-specific (cf. Lazarus & Folkman, 1984; Lehr, 1991; Maas & Kuypers, 1974; Mussen, 1985; Olbrich, 1985; Shanan, 1991; Thomae, 1988). For instance, the time perspective may change in very old age to the extent that individuals are being confronted with the fact that their life-time is limited (Kastenbaum, 1985; Kruse, 1987; Munnichs, 1966; Thomae, 1981, 1988), but this change will not always lead to changes in other aspects of the self.

Application of microgenetic and simulation methodologies can be expected to bridge the gap between trait- and process-oriented approaches. For example, variations in instructional set has shown that quite different age trajectories result when subjects are asked to describe themselves in the present with or without juxtaposition to the past or when they are asked to characterize the aging of others (Ahammer & Baltes, 1972; Harris, 1975; Heckhausen & Krüger, 1991). Thus, it is likely that the data-gathering scheme employed by Costa, McCrae, and others, where individuals are asked to fill out questionnaires about their present state of mind, is not optimally suited to reveal aging-related changes in personality and the self. There is increasing evidence that irrespective of 'objective' functioning, individuals may continuously adjust their frame of reference such that age changes in personality are compensated by a corresponding change in expectations (cf. Bäckman & Dixon, in press; Maciel et al. (1992). For example, when younger and older adults are asked to describe their health or to characterize their level of satisfaction, fewer age changes result (Baltes, P. B., 1991). It is likely, however, that such lack of age differences or age changes is

due to the fact that older adults evaluate their level of functioning in comparison with other older adults and not with their own past. These compensatory shifts in reference groups (Schulz, Heckhausen & Locher, 1991) may become evident if individuals are explicitly asked to review their lives, or to compare the present situation with their recent or remote past (Fooker, 1985; Kruse, 1992; Lehr, 1980; Maas & Kuypers, 1974; Thomae, 1968, 1988). For instance, in addition to asking individuals to answer items from personality questionnaires as it is normally done (e.g. with an implicit but unspecified point of reference), individuals could be asked to answer these items in the way they think they would have answered them a certain time ago (e.g. Ryff & Baltes, 1976; Woodruff & Birren, 1972). They could also be asked whether they have noticed any changes in self-related thoughts and feelings during the last few years, and, if so, in which domains, in what direction, and to what extent.

Real-time longitudinal studies employing these 'pseudo-longitudinal' data gathering techniques such as the Bonn Longitudinal Study and the Berkeley Study have provided a more differentiated picture of continuity and transformation than proponents of the psychometric trait-oriented view who, for the most part, have used standard self-report instruments. The Bonn Longitudinal Study, for instance, conducted extensive interviews to explore individuals' subjective construction of their past, present, and future (Lehr & Thomae, 1987; Schmitz-Scherzer & Thomae, 1983; Thomae, 1976, 1983). At the first of eight measurement occasions ($N = 222$), interviews regarding the past covered the entire biography. Explorations at later measurement occasions concentrated on biographical events and personal experiences which had occurred in-between the preceding and the concurrent measurement point. The Bonn analyses also were not restricted by an extant set of situation-invariant personality traits, but emphasized constructs such as life styles which were more open to developmental transformations.

In recent analyses of these data (Fisseni, 1985; Fooker, 1985; Olbrich, 1985; Thomae, 1988), it was found that individuals experience both continuity and change in different domains of personality, the life situation, and the environment. Changes were experienced primarily regarding the life situation (e.g. as an increase or, sometimes, a decrease in health problems), and with respect to social or physical aspects of the environment (e.g. as changes in the intensity of contacts to relatives, friends, and acquaintances, or as a change in residence from an independent living situation to an institution or the children's home). With respect to personality, basic belief systems and value orientations showed a high degree of stability and continuity, whereas coping styles were more likely to change. For instance, some individuals increased their ability to accept health-related constraints, and to appreciate the positive side of their current life situation. In sum, the results of the study were consistent with the hypothesis that behaviour-oriented aspects of the self are more likely to undergo change than basic personality characteristics.

Results from the Berkeley Study, another real-time longitudinal study

investigating personality development from the fourth to the eighth decade of life (Maas & Kuypers, 1974; Mussen, 1985), also focused on the concept of life style. Again, large inter-individual differences in the continuity of life styles were revealed. In particular, life-styles of men exhibited a greater amount of continuity than life-styles of women. The authors argue that the women in the sample were more affected by changes in the family cycle than men. For instance, they were more likely than men to remodel their future time perspectives and life-styles after children had left the house of the parents.

The issue of subjectively experienced continuity and change was also at the center of a recent cross-sectional study (Kruse, 1992). The study was designed to complement the Bonn Longitudinal Study, and comprised 480 participants aged 67 to 103 years. To examine subjectively experienced changes in personality characteristics, individuals were asked to describe the continuities and discontinuities of their own aging process. Thus, the study is a good example for the use of the 'pseudo-longitudinal' method described above in that individuals were explicitly asked to compare the present with the past.

Self-reports indicated that individuals experienced both gains and losses as they were growing into old and very old age. Personality development was primarily characterized by gains. For instance, individuals said that they were increasingly capable of perceiving the possibilities and limitations of their behavioural resources. Moreover, they felt that the increasing constraints on their future time perspective had made them more capable of selecting a set of goals and plans judged to be both important and attainable in the near future (e.g. in the coming weeks or months). Losses were conceived primarily in terms of functional capacity. Examples include increasing sensory and motor impairments, an increase in chronic pain, and the increasing dependence upon health services and caregivers.

INVESTIGATIONS INTO LIMITS OF FUNCTIONING (PLASTICITY)

The systematic exploration of the range (plasticity) of behavioural functioning is another main theme of aging research. Changes in plasticity are increasingly seen as the hallmark of aging (Baltes, P. B., 1987; Lerner, 1984). Plasticity or within-person adaptiveness refers to the fact that individuals perform in different ways and at different levels under varying experiential conditions. In particular, the notion of plasticity points to the latent potential of individuals, to what they could do if conditions were optimal. Kliegl and Baltes (1987) proposed three facets or tiers of functioning which further specify conditions for the assessment of plasticity: 1) baseline capacity indicates what a person can do without intervention or special treatment. 2) baseline reserve capacity denotes an individual's performance when, at one point in time, all available external and internal resources are activated to optimize performance. 3) developmental reserve capacity refers to the kind and level of performance an

individual can achieve if continued exposure to an optimal environment has extended the initially available amount of reserve capacity.

It follows from these definitions that age-related changes in plasticity are generally difficult to study by means of real-time longitudinal designs. This is even true if they involve some form of intervention because interventions (if used as an experimental manipulation in real-time longitudinal research) do not approximate the range and intensity necessary to explore the limits of plasticity. Under naturalistic circumstances, individuals do not activate their reserves unless they are forced to do so because of extremely challenging life-events or life-styles. Moreover, standardized assessment procedures as used in large-scale studies are often not appropriate to estimate an individual's possible range of performance. For instance, the administration of a standardized IQ test once per year does not provide an optimal context for the activation of cognitive resources.

To approximate limits (or peaks) of functioning, it is necessary to enlist many hours of practice and often years of guided tutoring (Ericsson, 1990; Ericsson & Smith, 1991). Microgenetic intervention studies and developmental situation studies are designed to approximate peak performances in the laboratory. Here, the focus is on inter-individual differences in short-term – 'microgenetic' – intra-individual change and on maximum possible performance. It is hypothesized that the obtained change function contains important and formerly hidden information about the functional status of an individual. This information may be used not only to estimate the possible range of developmental trajectories available to a given individual but also to understand the matrix of individual differences in aging existing in a given population.

Age differences in plasticity have been studied foremost in the domain of cognitive development, with microgenetic intervention studies demonstrating both the continued existence of cognitive plasticity in old age as well as sizeable age-related reductions in developmental reserve capacity (first research example, below). However, we believe that the notion of plasticity may also lead to a better understanding of the stability and maintained integrity as well as the possible breakdown of personality in old age. For instance, numerous studies have found that the self in old age continues to be a resilient system of coping despite the fact that major losses such as bereavement, chronic illness, and the death of close friends accumulate. Thus, it appears that the plasticity of coping processes is maintained or even refined throughout the entire adult life-span (second research example, below).

First example: old-age cognitive plasticity and its limits

The interest in old-age cognitive plasticity is guided by three main propositions. The first proposition states that descriptive aging research provides but a snapshot of a person's or cohort's location in a population of performance distributions. Because in such descriptive real-time aging research we do not

know the life-history of performance conditions that are at the foundation of each person's life circumstances nor their differences between individuals, it is difficult to compare persons as to their basic potential. The second proposition states that there is, especially in old age, reserve capacity which can be activated. This proposition originated in the 1970s (Baltes, P. B., 1973; Labouvie-Vief, 1977), and was originally meant to counteract the focus on decline that was historically dominant in gerontological research. The third proposition states that a loss in plasticity may be a hallmark of aging (Baltes, P. B., 1987; Coper, Jänicke & Schulz 1986; Shock, 1977). As to cognitive aging, these propositions have been applied primarily to the study of experience losses in the strength and range of cognitive potential, especially of 'fluid' intelligence or the 'mechanics' of the mind (Baltes, P. B., Dittmann-Kohli & Dixon, 1984; Cattell, 1971; Horn, 1982; Kliegl, 1992; Salthouse, 1991). Extensive and age-comparative intervention studies (e.g. up to 100 training sessions distributed over 1-2 years) have been conducted to explore the range of and age differences in cognitive plasticity.

Microgenetic intervention studies suggest that all three propositions are basically true, at least with respect to healthy individuals up to their 70s or early 80s. Fig. 8.2, taken from Baltes, P. B. and Kliegl (1992), both exemplifies and resolves this paradox. Subjects in this study participated in 38 experimental sessions distributed over about one year and were trained in the Method of Loci, a mnemonic technique for the ordered recall of word lists (Bower, 1970; Yesavage & Rose, 1984; Kliegl, Smith & Baltes, 1989). In the Method of Loci, subjects overlearn a set of locations or loci in an invariant order. After acquisition of this cognitive routing map, to-be-learned items are sequentially associated with each of the locations of the map by means of a mental image. To recall the items, subjects 'visit' each location, try to remember the mental image, and retrieve the target item.

First, this research shows that simple one-time observations are not sufficient to index a person's level of capacity. Secondly, the research demonstrates that most elderly persons are quite able to learn the Method of Loci, and by using it to perform outside the usual range of performance when recalling lists of words or digits (Baltes, P. B. & Kliegl, 1992; Kliegl et al., 1989). This is illustrated by the large training gains of older adults depicted in Fig. 8.2. The finding of substantive improvement over time is clearly consistent with the proposition that developmental reserve capacity is preserved in old age, and supports earlier findings from other domains of fluid intelligence (for a summary, see Baltes & Lindenberger, 1988).

On the other hand, the data displayed in Fig. 8.2 also support the third proposition of an aging-associated reduction in developmental reserve capacity. Even after very extensive training, old adults were not able to reach the level of performance reached by young adults after very few training sessions. Thus, although older adults were clearly capable of acquiring the Method of Loci and performing outside the range of typical recall performance, they showed sizeable performance deficits when compared to young adults and tested for

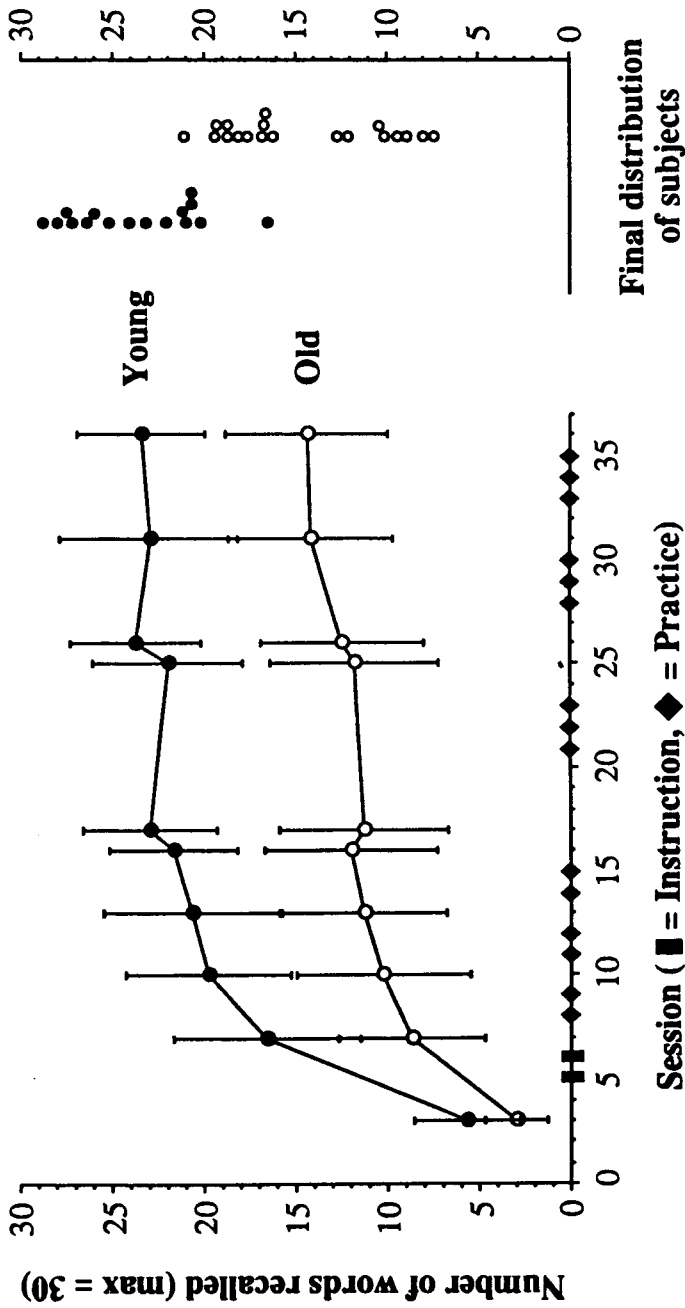


Fig. 8.2. Performance by young and old adults in serial recall of lists of words as a function of mnemonic training (left panel). The bars indicate standard deviations. In the right panel, individual scores are given for the last assessment sessions (36/37). (Taken from Baltes & Kliegl, 1992.)

limits of developmental reserve capacity. This negative age difference was substantial, resistant to extensive practice, and applied to all subjects. Note (see Fig. 8.2) that after extensive training none of the older adults (who were positively selected) performed above the mean of young adults.

Taken together, the findings amount to what Kliegl and Baltes (1987a; Baltes, P. B., 1991) coined the Janus-like character of old age and aging. Despite the continued existence of sizeable cognitive reserves, aging individuals seem to experience, perhaps with no exception, age-related losses in the strength and range of cognitive potential, especially in the mechanics of the mind. The articulation of this dual-sided view of cognitive aging was only possible by developing a coalition between real-time and microgenetic longitudinal research. Neither alone, would have been sufficient.

In future research, the boundary conditions of each of the propositions about plasticity need to be tested through a systematic exploration of subject characteristics such as age (e.g. young-old versus old-old; Willis, 1991), health status (Schaie, 1990b), control beliefs (Lachman et al. in press) and professional expertise (Lindenberger, 1991; Lindenberger et al. in press). Recent evidence suggests that the amount of developmental reserve capacity in old age may vary as a function of such and similar variables. In particular, the onset of senile dementia of the Alzheimer type seems to be associated with a dramatic reduction of developmental reserve capacity (Baltes, M. M. et al. in press). Developmental reserve capacity is also reduced in very old adults (Willis, 1991) and in old adults with cardiovascular disease (Schaie, 1990b). Finally, in the domain of imagery-based memory functioning, the existence of task-relevant pre-experimental knowledge and practice in the form of professional expertise seems to attenuate, rather than eliminate, age differences in developmental reserve capacity (Lindenberger, 1991; Lindenberger et al. in press). That elimination of negative age differences was not possible in this latter study, demonstrating the increasing role of biological aging as a limiting constraint for the aging mind.

In conclusion, we would like to add that the strategy of developmental simulation may also help to identify causes of age-related changes in cognitive plasticity. One may hypothesize, for instance, that effortful attentional processes are among the most prominent variables representing aging-related losses in brain efficiency at the psychological level of analysis. One way to test this hypothesis would be to identify treatments that presumably lead to an analogous impairment of attentional processes in young adults. The prediction would be that young adults exposed in this treatment would show a similar pattern of cognitive deficits as old adults. A recent study comparing the memory performance of old adults and young sleep-deprived or alcohol-intoxicated subjects is instructive in this regard (Nilsson, Bäckman & Karlsson, 1989).

Second example: coping with death and dying

The notions of plasticity and developmental reserve capacity are also applicable to what Jaspers (1965) termed the boundary situations ('Grenzsituationen') of

human existence. Situations of this kind may arise as a consequence of severe chronic illness, confrontation with one's own death and dying, and the death of close persons. The frequency of exposure to such events increases in old age, and some individuals may be confronted with them for the first time. Thus, the likelihood of experiencing a 'boundary situation' is probably higher in late than in early or middle adulthood.

In the following, we proceed from the assumption that there is a structural resemblance between testing-the-limits situations in cognitive intervention and the boundary situations of human existence. In both cases, individuals are confronted with a challenge that strongly deviates from what they normally experience in everyday life. In the case of cognitive intervention, the challenge is mainly on the cognitive plane; in the case of a boundary situation, the challenge concerns central aspects of personality and the self and its adaptive capacity (Brandstädter & Baltes-Götz, 1990; Brim, 1988, 1992; Filipp & Klauer, 1986; Kruse, 1987; Taylor & Brown, 1988).

An empirical examination of coping with boundary situations in the context of typical large-scale real-time longitudinal studies is difficult because these studies generally have a fixed schedule of measurement and do not preselect for the occurrence of boundary conditions (see, however, Wortman & Silver, 1990). Boundary situations may, or may not, occur between one measurement occasion and the next, and they may already date back for quite some time when the next measurement occasion takes place. Thus, although real-time longitudinal studies provide a differentiated picture of general individual differences in coping styles (Busse & Maddox, 1986; Costa & McCrae, 1988; Costa, McCrae & Arenberg, 1983; Lehr & Thomae, 1987; Mussen, 1985; Palmore et al., 1985; Schmitz-Scherzer & Thomae, 1983), they are not very informative if the goal is to better understand inter-individual differences in coping with boundary situations as well as the microgenesis of that process. Replicated single-subject designs with repeated measurements (for a review, see Jones & Nesselrode, 1990) are more appropriate in this case because both the beginning of measurement and the spacing of measurement intervals can be adopted to each individual and their matrix and flow of life events.

A recent study on death and dying (Kruse, 1987; cf. Kruse, 1991) may serve to illustrate the potential of this approach for a better understanding of individual differences in coping with death and dying as the ultimate boundary situation of human existence. Fifty-five elderly patients with an infaust diagnosis were closely followed by general practitioners and psychologists from the time of their release from hospital until their death. The investigation covered 6 to 24 months, depending upon how long individuals survived. The goal of the study was to examine intra-individual changes in confronting one's death and dying, and to elaborate forms of medical and psychological intervention that would facilitate the acceptance of one's death.

Two results are noteworthy. First, it appeared that patients were seeking out for persons and situations that closely matched their appraisal of and their feelings towards the situation. Thus they made efforts at structuring situations

and interactions such that the likelihood of maintaining a sense of subjective continuity was maximized. For instance, patients who were not willing or able to realize impending death refrained from interactions with persons who, according to their judgment, were likely to engage them into conversations about death-related issues. Moreover, these individuals were eager to demonstrate their preserved physical competence.

Secondly, in some individuals, the opportunity to share fears and sorrows with a confidant led to a pronounced improvement in subjective well-being. Initially, these individuals were deeply depressed and resigned; later on, they were able to consciously face – and finally accept – death. The possibility to engage in an intensive exchange was fundamentally new for these patients, given that they had not yet experienced something similar within or outside their families. The unique character of the interaction may have promoted behavioural and experiential development.

On the one hand, the findings of this study support earlier results showing that individual differences among elderly individuals in coping with stressful life events are influenced by personality characteristics and prior experiences with similar situations (Costa & McCrae, 1987; Lazarus & Folkman, 1984; Lehr, 1982; Maas & Kuypers, 1974; Shanan, 1991; Thomae, 1988). The findings, furthermore, demonstrate the usefulness of person-oriented, repeated single-subject designs for the investigation of coping with boundary conditions of human existence. On the other hand, because of a lack of microgenetic and interventive work, we are not yet in a position to specify the constituent processes or the range of individual adaptiveness to boundary situations of human existence. At the same time, this research (Kruse, 1987, 1991), because of its sensitive topic reminds us that we have to consider carefully the ethical implications involved whenever we move from descriptive real-time to experimental longitudinal work.

NORMAL VERSUS PATHOLOGICAL AGING

In essence, the distinction between normality and pathology in aging research is based on the assumption that growing old is not synonymous with becoming sick. Definitions of normal aging vary somewhat depending upon whether a more normative or a more descriptive (i.e. statistical) usage of the term is preferred (cf. Gerok & Brandtstädter, 1992; Fozard, Metter & Bryant, 1990). We prefer a more normative view by defining normal aging as growing old without a manifest illness, be it physical or mental. Pathological aging, on the other hand, refers to aging with clear signs of physical or mental pathology.

The heuristic function of this distinction is to urge researchers to identify those environmental, behavioural, and predisposing systems of influence which predict the incidence of both pathology and health in old age. Thus, the goal is not to classify the universe of aging patterns into two exclusive categories, but

to theoretically dissociate two time-related processes in order to better understand the reasons and conditions of their co-occurrence in the real world.

The main goals of longitudinal research on normal and pathological aging are prevention, early diagnosis and prediction of pathology, and rehabilitation. Again, the achievement of these goals requires the combinatorial use of various kinds of longitudinal methodology. Good examples for prevention are studies on cardiovascular disease. By now, several large investigations with random assignment of individuals to treatment and control groups have been carried out on this issue. An important result was that prevention was more effective in reducing morbidity than mortality (Fries, 1990). Studies on early diagnosis focus on the investigation of antecedent conditions of pathology in old age, and on the detection of early disease symptoms (Erlenmeyer-Kimling & Miller, 1986). Finally, longitudinal studies on rehabilitation are concerned with efforts at remediating already existing pathology. In order to explore the possible use of rehabilitative efforts, it is useful, however, to test the effectiveness of interventions in intensive single-subject studies and to offer constellations of treatments not available in reality as it exists today. Note again that this strategy of expanding and re-arranging conditions is at the foundation of microgenetic longitudinal work.

First example: early diagnosis of dementia

Perhaps the most typical example of a chronic disease associated with old age is senile dementia. The incidence rate for senile dementia of the Alzheimer type, for instance, is estimated to be about 5% by age 70, 15% by age 80, and 30% by age 90 (Häfner, 1986; Sørensen et al., 1986; Evans et al., 1989). At the behavioural level, the onset of Alzheimer's disease is marked by a global deterioration of cognitive functioning. Generally, 'fluid' abilities such as reasoning ability, orientation, and episodic memory are affected earlier in the course of the disease than 'crystallized' abilities such as verbal knowledge.

Currently, research efforts are directed toward identifying behavioural and neurophysiological signs of the disease as early and as reliably as possible (Christensen, Hadzi-Pavlovic & Jacomb, 1991). Longitudinal data are an indispensable part in this enterprise because they provide information on events and conditions that predict the incidence of dementia at later measurement occasions (Khatchaturian, 1985; Miller, 1986).

A re-analysis of data from the Aging Twins Study (LaRue & Jarvik, 1987) may serve to illustrate the problems faced by prospective real-time longitudinal studies on the early diagnosis of dementia. The authors examined 64 aging twins. Thirty-six of them were judged to be free of dementia on the basis of a careful mental status examination. A main result was that individuals who were judged to be demented at a mean age of 85 years had achieved lower scores on tests of cognitive functioning 20 years prior to the diagnosis. Moreover, they

experienced greater declines in vocabulary and short-term memory over this time period than those surviving to a comparable age without dementia. Thus, the results of this study seem to indicate that individuals who develop dementia in old age experience subtle cognitive declines many years before cognitive impairment becomes clinically evident.

Unfortunately, the interpretation of these data is not without problems. First, we know little about the ways in which sample attrition has influenced the results (Gruenberg, 1986). The original sample comprised 268, rather than 64 individuals. It is possible that individuals with certain types of dementia had a higher chance to drop out of the sample than healthy individuals or individuals with other types of dementia.

Another problem is the wide spacing as well as the small number of measurement occasions. Real-time longitudinal studies of this kind provide only restricted information about inter-individual differences in intra-individual change trajectories. Given the magnitude of inter-individual differences in the level of cognitive functioning present among elderly individuals (Schaie, 1988, 1990*b*), information on inter-individual differences in intra-individual change may yield a better separation of premorbid and cognitively intact populations (Labouvie, 1986). Thus, the onset of dementia may be better identifiable through measures of change than through measures of status.

Given the methodological and practical problems associated with real-time longitudinal studies on the early diagnosis of dementia, it is worthwhile to explore the potential of microgenetic longitudinal designs. With respect to the issue of dementia, there are theoretical reasons to believe that the microgenetic approach is especially promising. One guiding hypothesis, for instance, is that individuals at risk for dementia profit less from cognitive training than healthy older adults because their learning potential (developmental reserve capacity) is greatly reduced. Thus, it is a lower level of functioning in standard psychometric tests rather than the absence of training gains in the course of a few experimental sessions which is expected to predict a future pathology-related cognitive decline in real life.

A recent study (Baltes, M. M. et al., in press) supports this idea. Fifty-six healthy individuals and 25 individuals at risk for dementia were randomly assigned to either a training or a control group. The at-risk diagnosis was based on a standardized psychiatric interview that did not contain a cognitive assessment battery. Individuals in the two training groups received a series of five one-hour training sessions in a test of figural relations, a component of fluid intelligence.

The relevant data are shown in Fig. 8.3. Stepwise hierarchical regressions demonstrated that only healthy elderly profited from training, and that only post-training scores predicted the psychiatric at-risk diagnosis. Albeit preliminary and in need of replication, this study indicates that microgenetic studies with a focus on differential reserve capacity may prove helpful in offering a new window on the 'real-time', longitudinal emergence of dementia.

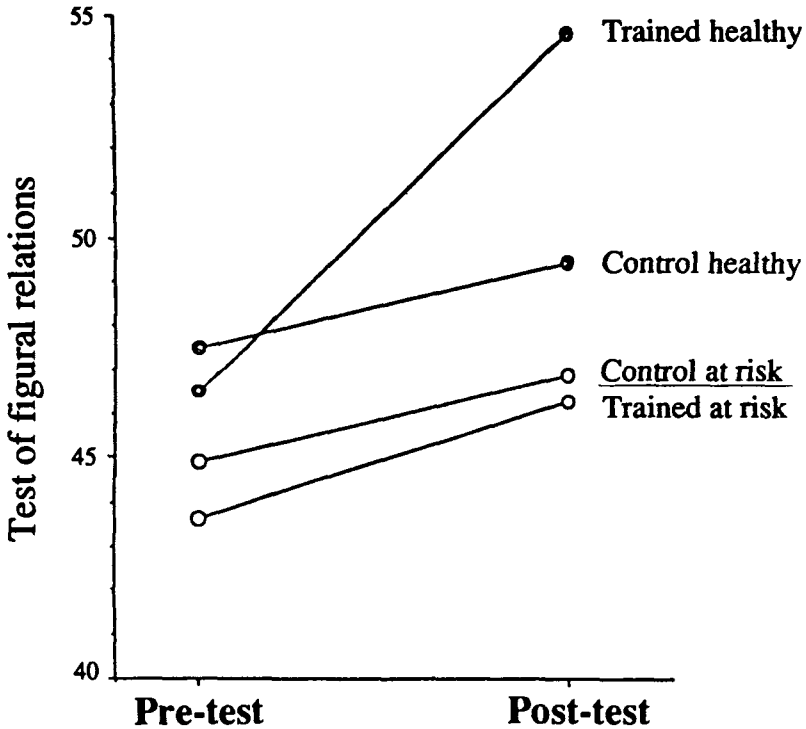


Fig. 8.3. Microgenetic intervention work on the early diagnosis of dementia (M. M. Baltes, Köhl, & Sowarka, in press). Changes in mean scores from pre- to post-test demonstrate significantly greater plasticity in the healthy trained group compared to the two control groups and the trained at-risk group. Differences in pre-test scores are not significant.

Second example: rehabilitation of pathology in old age

In addition to the identification of precursors and early manifestations of pathology, another task of longitudinal studies on normal versus pathological aging is to explore the degree to which pathological processes can be remediated or attenuated through *intervention* (Brody & Ruff, 1986; Häfner, 1986; Platt, 1988; Williams, 1985). These rehabilitation studies are microgenetic in nature because they focus on intra-individual change patterns as a consequence of prolonged treatment such as physical exercise, therapy, and drugs.

Rehabilitation studies have to cover a time period that is sufficiently long to determine the temporal extension (i.e. maintenance) of intervention effects and their possible interaction with age. The number of measurement occasions should be high enough to identify intraindividual change functions, and the scope of the variables under consideration large enough to encompass different

levels of functioning (e.g. biomedical parameters, abilities, coping styles). Furthermore, control groups with no treatment should be included whenever possible to disentangle the effects of intervention, spontaneous recovery, and aging.

A common finding of rehabilitation studies with elderly samples has been that recovery from illness is not so much a function of age than a function of other factors such as general health status, personality characteristics, social context, and the kind of disease under study (Brody & Ruff, 1986; Häfner, Moschel & Sartorius, 1986; Platt, 1988; Williams, 1985). A recent study (Kruse & Kruse, 1990) on the ambulant rehabilitation of elderly stroke patients ($N=112$; age range: 65 to 78 years) may serve as an illustration. Subjects entered the study after inhouse-rehabilitation had been completed. The intervention consisted of physiotherapy, ergotherapy, and speech therapy. In addition, psychological aspects of the intervention focused on coping with the illness, especially with its negative social consequences, and on the rehabilitation process itself. Study participants were followed for 18 months, and changes in psychomotor as well as verbal and non-verbal cognitive functioning were assessed at four measurement occasions.

As expected, the magnitude of performance improvement varied across domains and individuals. First, improvement in non-verbal cognitive abilities was less pronounced than improvement in psychomotor and verbal behaviour. Secondly, the magnitude of improvement was dependent upon the severity of the stroke, the existence and severity of other illnesses, and the psychological situation of the subjects. Specifically, individuals with depressive symptoms and a low sense of personal control were less likely to improve over time than other subjects. Definitely, this study illustrates that non-interventive 'real-time' longitudinal work is insufficient when the task is to identify optimal environmental conditions for rehabilitation. By definition rehabilitation research extends beyond existing realities.

MODELS AND CONCEPTIONS OF SUCCESSFUL AGING

Our final major theme of recent gerontological work is efforts at formulating and testing models of successful aging (Baltes & Baltes, 1990; Gerok & Brandtstädter, 1992; Rowe & Kahn, 1987). This effort encompasses at least three objectives: 1) the specification of relevant outcome variables (what are indicators of successful aging?), 2) the identification of risk and protective factors (which antecedent conditions are related to which desired or undesired outcomes?), and 3) the delineation of processes which are at the foundation of antecedent-consequent linkages (what are the underlying 'basic' mechanisms, behaviourally and societally, which generate the product?). Real-time and microgenetic longitudinal studies, in concert, are relevant for each of these questions and their inter-relationships.

Table 8.1 offers a glimpse at the factors and processes studied in work on

Table 8.1. *Successful aging: examples of positive outcome variables*

Objective role		Subjective role
Length of life	Mental health	Life satisfaction
Biological health	Autonomy	Optimism
Functional health	Social productivity	Personal control
Reserve capacity/adaptivity	Social integration	Self efficacy/agency
. mental		
. physical		
. social		
. economic		

Note:

Because of differences (variations) in personal and cultural traditions and values, no absolute definition of successful aging is possible (Baltes and Baltes, 1990).

successful aging. Depending upon one's view of the system 'human species' and one's preferences for what is significant in civilization and peoples' lives, different emphases result (Baltes & Baltes, 1990). Some researchers argue for the foremost importance of subjective indicators of the quality of life: 'Add life to years and not only years to life' is their primary motto. Others focus primarily on objective criteria such as length of life or its counterpart, mortality (including aspects of morbidity). Here is not the place to discuss the intellectual dynamics involved in the treatment of these issues. Rather, our focus is on demonstrating the omnipresence of longitudinal research and its use as a generic term rather than as being identical with real-time follow-up studies of single cohorts.

First example: life expectancy and morbidity of old age in the future

A good illustration of the importance of cohort-sequential longitudinal studies is the question of psychological or physical vitality (and its polar counterpoints, that is, morbidity and mortality) in old age. Which factors regulate psychological and physical vitality? How much potential for further improvement is there? Are today's older citizens more or less healthy than those of former generations? What are the prospects in health and well-being for the future of old age? Does the 'greying' of society lead to a healthier or more ailing state of old age? These are issues that take the centre-stage in current gerontology (e.g. M. Baltes, 1989; Baltes, P. B. & Mittelstraß, 1992; Bromley, 1988; Fries, 1990), and their treatment requires the skilful application of the full gamut of longitudinal methods.

Fries (1990), for instance, defines successful aging from a medical or public health point of view, as consisting of 'optimizing life expectancy while at the same time minimizing physical, psychological, and social morbidity' (p. 35). In addition, Fries (1980, 1990) has offered his own 'optimistic' view on the future

of old age and the possibility that future generations might increasingly age successfully; that is, live longer and with a smaller and smaller time-span of manifest morbidity. Two components are central to Fries line of argument. First, he argues that there is a definite and biologically based limit to our life-span (say about 85–90 years on average). Second, Fries maintains that within that fixed span of life, it is possible through healthier life-styles and improved medical treatments to delay the frailties of old age until very old age. In short, morbidity in future old age might be increasingly 'compressed' into smaller and smaller time spans before death.

For research endeavours, the Fries model implies an ontogenetic 'longitudinal' and a historical 'cohort-comparative' perspective and prediction. If his compression of morbidity model is correct, the onset of infirmity (morbidity) in more recent and especially future cohorts (generations) would occur later and later in old age; and in addition, the life-time available for healthy aging would increase more than the average life expectancy. The model, furthermore, implies that compression of morbidity should be evident only if the lifetime of individuals has reached an age sufficiently close to their biological maximum (Fries, Greene, & Levine, 1989).

In current gerontology, this optimistic view of Fries on the future of old age is juxtaposed by more pessimistic views (e.g. Krämer, 1992; Schneider & Brody, 1983; Schneider & Guralnik, 1990; Verbrugge, 1984). According to these pessimistic views, just the opposite is true for future aging cohorts. When populations, on average, live longer and longer, the likelihood increases for old age to become an increasingly sick state of life. And indeed, such a pessimistic view also has its empirical and theoretical foundations. Consider just the following two perspectives. In modern times, more and more biologically 'vulnerable' or 'weak' persons receive enough medical and social support to reach old age. In other words, the demographic 'greying' of society is actually correlated with a decrease of the magnitude of 'positive selection' during ontogenesis. In addition, there may be an added effect of life-prolonging efforts of medical technology during the very last phase of life. In short, the argument of the pessimist view of the future of old age goes: the older a population, the larger the proportion of biologically 'weak' and 'sick' individuals; and this, in addition to the illnesses which are characteristics of old age in the first place.

The evaluation of such opposing views requires longitudinal work: real-time, cohort-comparative, and interventive (Fries, 1989, 1990). For instance, to estimate the power and causal direction of risk factors (such as smoking, hypertension, obesity, or physical inactivity), it is necessary to observe longitudinally individuals as they age, who differ in these characteristics, and who have changed status in the risk factors involved (see also, Rutter, 1988a). Secondly, to understand and estimate the role of historical change and its connection with ontogenetic processes, it is imperative to conduct cohort-comparative longitudinal work, that is, to follow the longitudinal development of several generations.

The need for real-time, cohort-comparative, and interventive longitudinal

work applies to each of the components of Fries' model. One component is the assumption of a biologically fixed maximum life-span. This assumption evolved and is continuously tested by comparing age-specific life expectancies in successful cohorts, such as life expectancies of 70-year-olds in 1900 vs. 1950. Fries' conclusion in this regard is that there has been very little cohort or historical increase in life expectancy for the very old of each generation. Such a plateauing of life expectancy for the very old suggests to Fries that his assumption of a biologically fixed life-span is a reasonable one.

The second major assumption of Fries' compression of morbidity model is that older persons of the same age become healthier and healthier. Such a finding is part of the Goteborg Longitudinal Study which reports increased health for the average 70-year-olds across recent cohorts (Svanborg, 1985). Fries (1990) summarizes major American work which equally attests to a decrease in age-specific incidence of chronic disease. House et al. (1990) add another variation. In addition to cohort comparisons, they include variations of socio-economic status. This added comparison elucidates an important factor of social differentiation. By this addition, House et al. (1990) were able to show that the compression of morbidity model (*more healthier than sick life-time associated with living longer*) seems to be true for the upper, but not for the lower end of the socio-economic stratum.

The discourse surrounding the debate about the compression of morbidity model also makes explicit the importance of interventive and microgenetic longitudinal work. There is an increasingly large body of data aimed at examining the role of factors aimed at reducing risk or improving protection or 'reserve capacity' as we call it in our own work on the aging mind (Baltes, P. B. & Lindenberger, 1988; Kliegl & Baltes, 1987*a, b*). Bortz (1991), for instance, summarizes extant intervention work on the role of physical activity on morbidity and mortality, Fries (1990) offers a synopsis on the effect of medical interventions aimed at studying the effect of changes in health habits including the use of seat belts, and Masoro (1991), in his recent Kleemeier Award address at the Annual Meetings of the Gerontological Society of America (in press), demonstrates how longitudinal data on the effect of nutrition on longevity were elucidated by long-term and short-term animal research, in which the mechanisms and components involved were made more explicit through simulations of different life-histories (see Denenberg et al. (1968) for an early line of work on the experimental simulation of life-histories).

The corpus of data on morbidity and mortality and the future of an aging society is too extensive to be summarized here. The issue is further complicated by the fact that morbidity and mortality are not as highly correlated as one might assume (Fries, 1990). We also do not want to take a particular position on the nature of the evidence. The point here is to show the importance of viewing longitudinal methodology as a generic term with many faces. If the goal is to empirically evaluate the tenability of the compression of morbidity model, it is imperative to carry out cohort-sequential and experimental-interventive work.

Second example: psychological mechanisms of good (successful) aging

The same general perspective applies to the psychological study of aging well (Baltes & Baltes, 1990; Featherman, Smith, & Peterson, 1990). To illustrate, we focus on the role of certain processes of life management which individuals use to regulate their aging, behaviourally and experientially (e.g., Baltes, M. M. & Carstensen, 1991; Brandstädter & Baltes-Götz, 1990, and this volume; Brim, 1992; Schulz et al., 1991).

One meta-model of successful aging is that of 'selective optimization with compensation' (Baltes & Baltes, 1990). This model is a meta-model in the sense that its basic components (selection, optimization, compensation) identify general, quasi-universal characteristics of successful aging. A central feature of life-span development is the management of a shifting balance between gains and losses. During adulthood, with increasing age, the balance shifts towards a less positive ratio until, in old age, losses begin to outweigh gains, at least in our subjective pattern of expectations about the life course (Baltes, P. B., 1987; Heckhausen, Dixon & Baltes, 1989).

To achieve the management of this life-span developmental task, Baltes and Baltes (1990) posit that individuals, as they age, 'select' (passively or actively) domains for continued achievement and withdrawal, and they attempt to 'optimize' their functioning in the areas selected. In addition, they search for, and practise, 'compensation' when their levels of potential or skill fall below required levels. The model of selective optimization with compensation, then, proceeds from the assumption that, despite much individual variation, there is a fixed framework for the course of life: a reduction in reserve capacity implies less and less potential for positive change (gains). Continued plasticity (Lerner, 1984) permits, however, optimization and compensation aimed at maximizing gains in select areas and minimizing losses in others.

How this generic task of the management of a shifting balance between gains and losses is realized, depends, of course, upon the specific personal and environmental conditions. The model is generic (universal), its implementation, however is person and culture-specific. Table 8.2 offers three examples (music, running, and golf) using personal histories and observations offered by three persons who have focused on different domains as targets of selective optimization with compensation.

What about longitudinal research on the process selective optimization with compensation? The example used for illustration is the role of expectations and management strategies which operate when selection, optimization, and compensation take place, passively or actively. Among the central putative mechanisms of personal management of a shifting ratio between gains and losses are changes in goals and goal transformations (Brim, 1992) as well as changes in styles or forms of action control and coping (Baltes & Baltes, 1986; Brandstädter & Baltes-Götz, 1990, this volume). We are also interested in learning

Table 8.2. *Selective optimization with compensation: everyday examples*

Source	Selection	Optimization	Compensation
Concert pianist (Rubinstein)	Fewer pieces	More practice	More contrasts in speed of play
Long-distance runner	Easier courses Fewer competing activities	More practice New strategies (e.g. diet)	New and varied footwear Prevention of injuries (e.g. warm-up)
Senior golfer (Morehouse)	Fewer and shorter courses Time of day	More sensori-motor training Shift practice from driving range to green and short play	Change in club selection (e.g. higher woods, longer shafts) Change stance to calibrate for loss of balance

whether these processes of management of a shifting ratio of gains and losses are effective in the sense that they protect the aging person from a loss of self-esteem.

The significance of descriptive real-time longitudinal work on these topics has become paramount. First, longitudinal research has shown that older individuals, indeed, do not show the widely held expectation of a major loss in self-esteem and sense of control (Bengtson et al., 1985; Lachman, 1986). Older persons, by and large, report levels of well-being, self-esteem, and personal control that are comparable to levels reported by younger adults. Such an outcome, because the 'objective' state of older individuals is expected to be less positive (Baltes & Baltes, 1990), may be considered a surprise and needs explanation. Here, longitudinal research on styles of life management and coping becomes relevant, and there is a dearth of relevant work. As Brandtstädter and his colleagues (Brandtstädter & Baltes-Götz, 1990) have demonstrated, however, older adults exhibit coping strategies that focus increasingly on accommodative rather than assimilative goal definitions and goal realizations. With age, we become more inclined to adjust to new levels of what is possible in principle: certain goals are ignored, other goals are lowered, still other goals are transformed, and goals are stretched in time (Brim, 1992).

Such real-time longitudinal work needs expansion, however, and there is beginning to be evidence about how descriptive longitudinal work can be combined with microgenetic simulation of the developmental processes involved. One example is consideration of processes of self-referent thought in the management of gains and losses, and of our expectations about our futures changing with age (Baltes, M. M. & Carstensen, 1991; Schulz et al., 1991; Cross & Markus, 1991). Markus and her colleagues, for instance, have focused on the role of possible selves and how the choice of one's self-focus can be used in maintaining self-esteem and giving new direction to life.

Of particular significance as an exemplary case of microgenetic longitudinal work on the nature of coping in old age is the short-term, but highly intensive, observational work conducted by Baltes, M. M. and her colleagues in nursing homes and private residences (Baltes, M. M., 1988; Baltes, M. M. & Wahl, 1991; Baltes, Wahl & Reichert, 1991; Wahl, in press). When older adults show increasing passivity in mind and behaviour, the traditional view was that this is a function of lack of autonomy, dependency, or learned helplessness. By observing in detail, over weeks and months, the specific nature of interpersonal transactions between elderly persons and their social partners surrounding dependency-events and by combining such descriptive observational work with interventive strategies, Margret Baltes and her colleagues demonstrated that the traditional 'longitudinal' picture of the aging process needs re-interpretation. First, they showed that there is more plasticity in the age-associated evolution of dependency than would be expected from real-time longitudinal research. Secondly, they could demonstrate that not all of dependency is dysfunctional. When older adults show dependent behaviour, this is often not due to a lack of competence. Rather, dependent behaviour in the elderly can be associated with positive outcomes such as a sense of control over the social environment and the production of social contact. Through microgenetic longitudinal work, then, it was possible to elucidate with more clarity the multi-dimensional and multi-functional nature of dependency and its modifiability (plasticity). Achieving this level of insight would have been impossible with real-time longitudinal work alone.

OUTLOOK

The foregoing research illustrations from the study of human aging converge on the same general conclusion: real-time longitudinal studies, of course, are an essential part of research on human aging. They are a required part of developmental scholarship. But, despite their complexity, especially in implementation and quality control (Magnusson & Bergman, 1990), simple real-time studies are not enough. To understand antecedent-consequent relationships in ontogenesis, their degrees of magnitude, their causal directions, the nature of the underlying mechanisms, and the intricate relationship between ontogenesis and social change, it is necessary to rely on a broad spectrum of well-coordinated longitudinal designs: descriptive and interventive, single cohort and cohort-comparative, real-time and simulated-time.

As a concluding observation, we reiterate another argument why we firmly believe that research in human aging needs to treat 'real-time' longitudinal research in a perspective which includes a cautionary stance about its final power as a measure of what is true and possible in human development. Of all the periods of the life-span, old age is the newest in terms of the history of civilization. In one important sense, old age is 'young', that is, it does not have the benefit of a long and carefully refined cultural history of human care and tradition as would be true for childhood or adolescence. Were we to attend,

therefore, predominantly to findings from real-time longitudinal studies of extant cohorts, we would continuously reify the cultural past, we would omit other outcomes that are possible in principle (Baltes, P. B. & Mittelstraß, 1992). The future of old age, therefore, is also critically dependent on what researchers can create and simulate in their laboratories and not only on what culture has accomplished thus far. Let us revisit the example of cognitive aging as an example. Real-time longitudinal work suggested that the reality of the aging mind was decline, at least after the sixth decade of life. It was, however, short-term and interventive 'microgenetic' work which helped us understand not only the nature of the processes involved, but especially the conditions for continued plasticity.

Aging and old age, then, are not fully fixed biological and cultural realities. They are in flux. It is also for this reason that we argue for an expanded conception of longitudinal methodology. The final power of real-time longitudinal methodology hinges on its creative combination with other kinds of longitudinal designs that permit us to look more closely at the constituent processes and to look beyond.

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