Center for
Lifespan Psychology

Contents

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But … its eminent modifiability, and its predisposition to self-initiated action, may it develop little or much, and may it differ in amount between different individuals, is among the immutable features of humankind, which can be found wherever humans exist.
Johann Nicolaus Tetens, I, p. 766

J. N. Tetens (1736–1807), philosopher of the Enlightenment Era

Introductory Overview

The Center for Lifespan Psychology was created in 1981 when Paul B. Baltes was appointed Director. Ulman Lindenberger joined the Center as incoming Director in Fall 2003 and took over full responsibility as the Center's new Director in Summer 2004. Research and theory of the Center for Lifespan Psychology is conducted primarily from the perspectives of the field of developmental psychology. A special focus of the Center is on the study of plasticity (modifiability) of human behavior across the entire lifespan, including its societal and neuronal correlates, antecedents, and consequences (see Figure 1). The Center has been a major player in advancing the fields of lifespan psychology and the study of aging. It continues to pay special attention to the age period of late adulthood and old age, which offers unique opportunities for innovation, both in theory and practice.

Conceptual Orientation

The psychology of the ages of life, from childhood to old age and their interconnections, is the substantive scope of developmental psychology. Developmental psychologists aspire to understand the behavioral, mental, social, motivational, and interpersonal characteristics and processes that constitute, accompany, and modify lifetime development. Major sources of lifespan development include (a) the long-term (distal) consequences of biocultural evo-

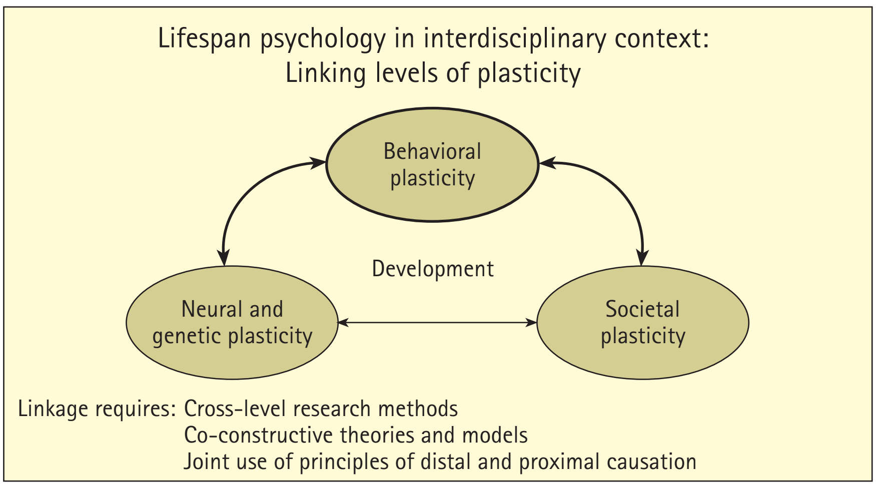

Figure 1. Lifespan development as bio-cultural co-construction. A central goal of lifespan psychology is to describe, explain, and optimize human potential and to identify its societal and neural causes and consequences. See also Baltes (2004), Li (2003), and Lindenberger, Li, and Bäckman (in press).

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lution as expressed, for instance, in genome-driven brain plasticity and (b) the ongoing opportunity and inequality structures of society at large, and especially the more proximal microenvironments, such as families, friendships, schools, universities, firms, senior homes, and residential locations within which individuals live. In addition, the role of individual factors and processes, such as individual differences in learning histories, mental capacities, motivation, self-regulation, and strategies of life management take center stage when psychologists attempt to understand the course of life, including its many variations and faces.

As illustrated by the foregoing observations on the general sources of human development, developmental psychologists concern themselves primarily with the more proximal sources of individual behavior during the lifespan. However, to achieve a fuller understanding of individual development, it is necessary for developmental psychologists to engage themselves in collaborative efforts with the biological and the social sciences. This is the special opportunity of the transdisciplinary view of human development that guides work in the four centers of the Max Planck Institute for Human Development. In this vein, there has been considerable interaction of scientists in the Center for Lifespan Psychology with researchers in the other centers or from other institutions. A good example is the Berlin Aging Study in which medical researchers and behavioral and social scientists collaborate in the pursuit of knowledge about human aging in a changing society. In 2004, the Max Planck Institute for Human Development was coopted to the Berlin NeuroImaging Center, a multisite center funded by the Federal Ministry of Education and Research also involving the Charité (University Medicine Berlin) and the Physikalisch-Technische Bundesanstalt. In a newly established project of the Berlin NeuroImaging Center, researchers from the Center for Lifespan Psychology, the Charité, and the Karolinska Institute at Stockholm are cooperating to identify neurochemical correlates of adult age differences in behavior and cognitive plasticity.

During the recent decade, lifespan and life-course research have become a major focus of the Institute's research profile. This emerging focus has led to an increased cooperation between all centers. The shared overall framework is the coordination of several lines of inquiry—psychological, sociological, educational, and, in cooperation with other institutions, neuronal—to understand the evolution and ontogeny of human behavior.

A sample of questions that developmental psychologists typically study is the following:

- How do nature and nurture interact in determining development, such as the emergence of the mind?
- How do relations between body and mind change with age?
- How and why do functions, such as intelligence and memory, vary within and across individuals, and how and why do they change with age?
- What are the special bodies of knowledge and dispositions, such

as life skills and wisdom, that make for successful aging?
- How and to what end do individuals acquire and maintain a sense of personal control? How do they plan and manage their lives?
- How do aging individuals cope with rapid technological change, and how can human engineering technologies facilitate the transition to old age?
- How do young children learn to coordinate their behavior with others, and how does interpersonal action coordination affect social and cognitive development?

These and similar questions are pursued with the aim to identify both the commonalities and the between-person differences in human development. The human condition is regarded as co-constructed by biology and culture and, therefore, offers much room for nonnormative (idiosyncratic) choices and pathways. In this spirit, additional topics of great concern are the ways by which individuals and their close partners can improve their own development as well as that of others.

What is special about the general research orientation that scientists in the Center for Lifespan Psychology display and use as mental scripts? The theoretical and methodological perspectives and research agenda of the Center are summarized below in seven propositions. These propositions reflect what may be considered the theoretical framework of lifespan psychology (Baltes, 1987, 1997; Baltes, Lindenberger, & Staudinger, in press; Li, 2003; Lindenberger, 2001).

(1) Human development is viewed as occurring throughout the lifespan, implying cumulative-continuous as well as innovative-discontinuous developmental processes and outcomes.

(2) The process of human development from childhood into old age is considered to be an age-related change in adaptive capacity, in which there is a continuous interplay between growth (gains) and decline (losses).

(3) Understanding psychological development requires theoretical models that are often identified as contextual, interactive, or dialectical. For example, ontogenetic development occurs in the context of biosocial systems that exert biocultural influences. Three macrostructural components are particularly relevant: (a) social change, (b) the system context provided by familial and/or generational transmission, and (c) the lifespan ecologies associated with social settings, such as the family, school, work, leisure, health care, and retirement.

(4) The plasticity or basic potential of development (i.e., its range and constraints) is a central focus of investigation. Of major concern are studies exploring the functional range within which individual developmental processes can be influenced. Objective and subjective knowledge about developmental plasticity (in either a positive or a negative direction) is essential for the formulation of strategies optimizing human development.

(5) Human activity and goal orientation during lifespan development are other conceptual emphases that guide the Center's studies. Such an emphasis makes explicit the role that individuals play as producers of development—both their own as well as that of others.

(6) Another conceptual orientation is the notion of interactive minds. This orientation, an orientation that has much in common with the field of cultural psychology, reflects the notion that the psychological nature of the social context of human development is essentially collective and involves internal as well as external mechanisms of social transactions and collaborations.

(7) Understanding the nature of human development is facilitated by a perspective that attempts to link components of functioning into an integrated whole, that is, the individual. To this end, the search for general models of successful development and aging is a leitmotif of research in the Center. One such model currently under investigation postulates that selection, optimization, and compensation constitute key functional elements of the developmental process. It is argued that their dynamic coordination and orchestration results in successful development, that is, the maximization of gains and minimization of losses across the lifespan.

The following summary of the research programs of the Center is selective rather than comprehensive. Its purpose is to highlight samples and illustrate the lines of inquiry that Center scientists pursue in making a contribution to research and theory in lifespan psychology as well as its implications for social policy and the future of humankind.

Lifespan Psychology: Implications for Conceptions of Intelligence and Cognition

Lifespan conceptions of intelligence provide a first general theoretical orientation of the research conducted at the Center (Lövdén & Lindenberger, 2005). One domain of psychological research that has undergone major changes in theoretical orientation during the last decades is the psychology of intelligence. Research on lifespan intelligence was one of the contributory sources for this change. To illustrate, the psychometric tradition of intelligence testing pioneered, for instance, by Stern and especially Binet close to 100 years ago is very much ingrained in people's everyday thinking of intelligence. In the minds of the general public, being smart and having a high IQ (Intelligence Quotient) is synonymous. In contrast, over the last couple of decades, the climates of the scientific inquiry about intelligence have shifted from the IQ-based tradition—usually measured with respect to limited sets of abilities associated primarily with academic performance and work productivity—to broader inquiries about the contextual and functional aspects of intelligence and its underlying cognitive, social-interactional, and neuronal sources. A new and productive integration of the psychometric, cognitive-psychological, cognitive-neuroscience, and ecological traditions is in the making.

Implicit in the psychometric approach is a focus of measuring intellectual abilities, as opposed to understanding the causes, contexts, and functions of intelligence. Specifically, this approach views intelligence as reflecting a collection of static abilities that characterize a person, as opposed to a dynamic system of contextualized and adaptive cognitive functions that individuals continue to acquire throughout their life course. One aspect of the Center's research program focuses on the theoretical and empirical investigations of lifespan intellectual development. This program has contributed to the conceptual shift in intelligence research by reconceptualizing intelligence as a system of contextualized and ontogenetically driven adaptive cognitive functions. We pursued several lines of inquiry in our search for a dynamic view of intelligence that is both contextually and lifespan sensitive. Originally, our approach was guided by cognitive training research demonstrating more plasticity of the aging mind than is commonly assumed, and subsequently by age-comparative research on limits of functioning confirming the existence of a lifespan function of cognitive plasticity (Baltes, Lindenberger, & Staudinger, in press). Meanwhile, we have broadened this approach by adding new theoretical orientations, if not new conceptions, that stem from efforts to further integrate cognitive experimental and contextual thinking with the psychometric traditions of intelligence testing.

A key characteristic defining intelligence and intelligent behavior is its adaptive value in novel situations. Lifespan contexts include continuity and change in contexts of adapta-

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tion. In old age, for instance, an increasingly larger share of cognitive resources is invested into maintaining bodily functions rather than "academic" pursuits. Seen from this perspective, intelligence is intrinsically related to a lifespan perspective of human development that considers development as a process within which individuals continue to adapt their bodies of factual and procedural knowledge to changes and transformations in biological, environmental, and cultural constraints that inevitably take place throughout their life course.

In this spirit, and by extending the Cattell-Horn theory of fluid-crystallized intelligence (Cattell, 1973), we have presented a new dual-process model of intelligence (Baltes, Staudinger, & Lindenberger, 1999; Krampe & Baltes, 2003; Lindenberger, 2001) that highlights two distinct, but interacting dimensions of intellectual functioning (see Figure 2): the biologically driven cognitive mechanics and the culture-based cognitive pragmatics of the mind. On the one hand, the cognitive mechanics are basic information-processing primitives for the memorizing and learning that people are capable of. They reflect the neurophysiological architecture of the mind as it has evolved during biological evolution. The speed, accuracy, robustness, and coordination of elementary information-processing mechanisms index cognitive mechanics. The primary substrate of cognitive pragmatics, on the other hand, is culture-based knowledge that is acquired through cultural learning and life experiences. Prototypical examples of cognitive pragmatics are being able to speak and understand the social implications of language, to acquire the knowledge and skills related to professional expertise, or the kind of life skills that are necessary to navigate the modern world.

In the following, we describe two general lines of our ongoing research aimed at extending conventional models of intelligence from the perspective of lifespan psychology. The first line of research focuses on the relations between cognitive mechanics and pragmatics with biological and cultural factors and their differential lifespan trajectories. A second line of research that has been motivated by our concept of the cognitive mechanics is the investigation of resource management in sensorimotor functioning. A third line, which comprises the study of wisdom of life longings, is described in the project reports.

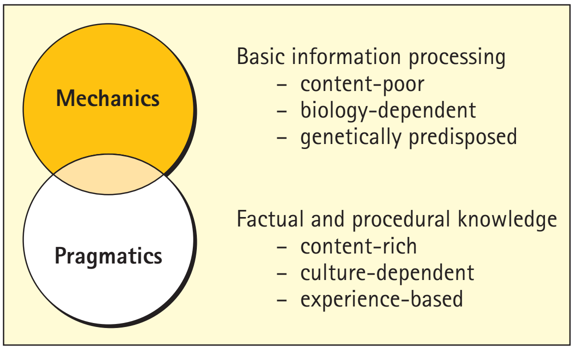

Figure 2. The dual-process model of lifespan intellectual development distinguishes between the cognitive mechanics and pragmatics of intellectual functioning (adapted from Baltes, Staudinger, & Lindenberger, 1999).

Sources of Age Differences in Cognitive Mechanics Versus Pragmatics

To test the dual-process model of lifespan intellectual development, our research, thus far, directly examined the relations between these two aspects of intellectual functioning and biological and cultural factors, and their differential lifespan trajectories. In our view, sensory and intellectual functions are closely related when cognitive primitives (mechanics) are operative in the task at hand. Congruent with this expectation, our empirical findings show that among old adults basic sensory processing is much more highly correlated with the cognitive mechanics than with cognitive pragmatics (see Figure 3). In contrast, sociobiographical predictors correlate more with cognitive pragmatics than with cognitive mechanics (Lindenberger & Baltes, 1997). The association between the more biology-based sensory-sensorimotor processes and cognitive mechanics is a robust phenomenon that generalizes to measures other than the average level of performance. For instance, within-person week-to-week fluctuations in old people's sensorimotor performance also correlate highly with the cognitive mechanics. Accordingly, old people who varied more in their walking performance from week to week showed worse episodic and spatial memory (Li, Aggen, Nesselroade, & Baltes, 2001).

Given that biology and culture co-contribute differentially to the mechanics and pragmatics of intelligence, investigations of how these two aspects of intellectual functioning develop, maintain, and decline throughout life could offer insights into the complex and co-constructive interplay between the individual's biological and cultural "inheritances" in development (Baltes, Reuter-Lorenz, & Rösler, in press; Li, 2003; Li & Lindenberger, 2002).

Drawing data from a lifespan sample covering the first to the eighth decades of life, we found differential lifespan trajectories for cognitive mechanics and pragmatics in line with our theoretical expectations. As is true for research on the fluid-crys-

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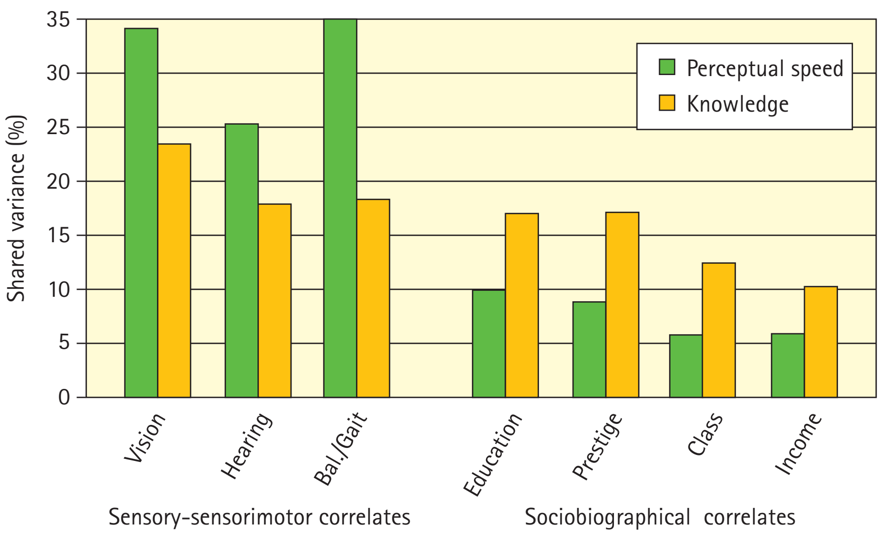
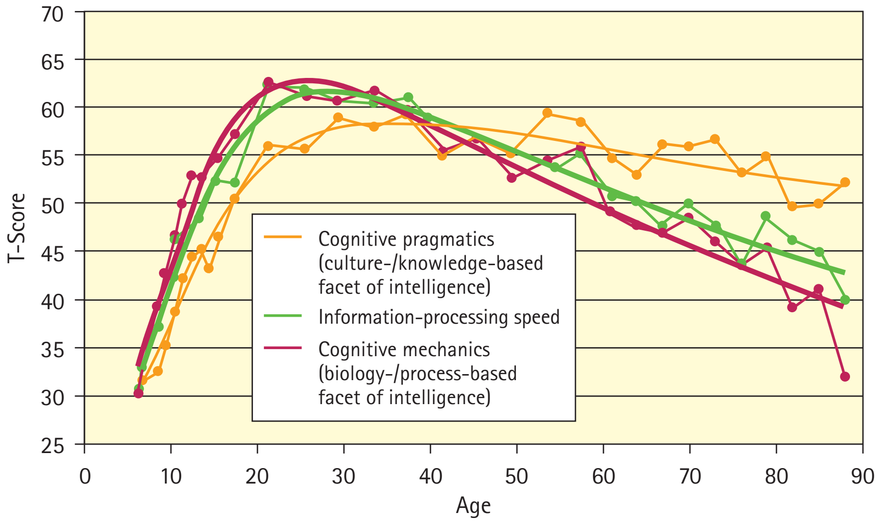


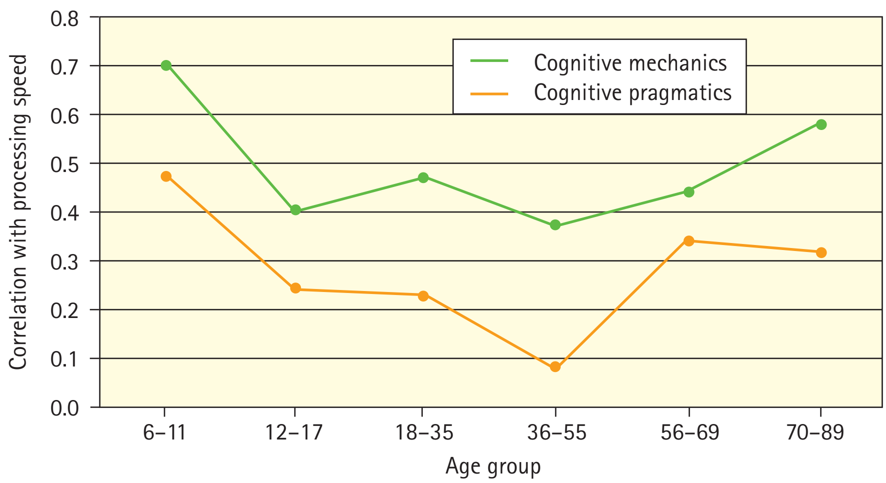
Figure 3. Differential correlational links of perceptual speed (a marker of the mechanics) and verbal knowledge (a marker of the pragmatics) to biological and sociobiographical indicators in old age (adapted from Lindenberger & Baltes, 1997).

Figure 4. Lifespan age gradients of cognitive pragmatics, cognitive mechanics, and processing speed (adapted from Li et al., 2004).



tallized distinction, cognitive mechanics display an earlier growth pattern up to early adulthood. The growth of cognitive mechanics primarily driven by brain maturation can then be invested into the acquisition and refinement of culture-based cognitive pragmatics. However, because of their close ties to biology and genome-based determinants, continuous losses of cognitive mechanics start early in adulthood. In contrast, the culture-based pragmatics, represented by the abilities of knowledge and language, have a later onset of decline which is less pronounced. In old age, however, the role of biology-based cognitive mechanics in regulating the cognitive pragmatics increases (Ghisletta & Lindenberger, 2003). Details in our evidence have provided further empirical support for the neurobiology versus acculturation distinction between these two domains of intelligence (Li, Lindenberger, Hommel, Aschersleben, Prinz, & Baltes, 2004). The lifespan age gradients of information-processing speed correspond very well with the age gradient of

Figure 5. Correlations between processing speed, cognitive mechanics, and cognitive pragmatics across six continuous age groups (adapted from Li et al., 2004).



cognitive mechanics, but much less so with cognitive pragmatics (Figure 4). Furthermore, overall information-processing speed correlated more highly with cognitive mechanics than with cognitive pragmatics, and especially at both ends of the lifespan (Figure 5).

Lifespan Differences in the Allocation of Cognitive Resources

In addition to the efficiency of basic information processes, the category of cognitive mechanics also encompasses the allocation of cognitive resources. Flexible resource allocation is especially important whenever the individual is faced with multiple tasks or situational constraints. An example of these tasks or situational demands comprises of basic sensorimotor functions, such as maintaining balance or walking while talking to a friend. Everyday life, for the most part, consists of such multitask situations. In the context of lifespan development, age brings with it different adaptive demands for individuals at different parts of their life course. Basic sensorimotor functions, such as postural stability and walking accuracy, lose efficiency in later adulthood because of decreased muscular strength and reduced peripheral vision, as examples. As a corollary, we argue that such emerging deficits in the coordination of bodily functions require more and more cognitive resources. To illustrate: In our studies, we systematically combined sensorimotor tasks of varying difficulties (i.e., walking with or without obstacles, balancing on a stable or moving platform) with cognitively demanding tasks (memorization) (K. Z. H. Li, Lindenberger, Freund, & Baltes, 2001; Lindenberger, Marsiske, & Baltes, 2000). Using dual-task and training research paradigms, the results suggest that older adults invest considerable cognitive resources to compensate for the decreased efficacy of their sensorimotor functions. On a larger scale, we assume that in later adulthood a considerable amount of cognitive resources, such as mechanisms for attentional control, tends to be permanently captured by sensorimotor functions that are predominantly automatized in younger adults. Unfortunately, these cognitive resources also decline with advancing age. In combination, these two classes of changes result in increasing demands on decreasing resources, and constitute the quandary of behavioral aging (e.g., Lindenberger, Marsiske, & Baltes, 2000). In our view, a key purpose of human engineering technologies is to attenuate the adverse effects of this quandary on development in later adulthood, old age, and very old age. Progress toward this goal requires the integrated consideration of sensory, motor, and cognitive changes (Lindenberger & Lövdén, in press).

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The Mastery of Life: Selection, Optimization, and Compensation (SOC)

A second general theoretical orientation of research in the Center for Lifespan Psychology is motivated by the question of how people develop successfully and avoid negative outcomes. To gain a better understanding of the factors contributing to successful development, that is, the simultaneous maximization of gains and minimization of losses, we attempt to specify the behavioral and cognitive strategies by which people, individually and collectively, master their lives. The focus of our theory is on the orchestration of selection, optimization, and compensation.

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Baltes, P. B., & Baltes, M. M. (1990). Psychological perspectives on successful aging: The model of selective optimization with compensation. In P. B. Baltes & M. M. Baltes (Eds.), *Successful aging: Perspectives from the behavioral sciences* (pp. 1–34). Cambridge, UK: Cambridge University Press.

According to the model of selection, optimization, and compensation (SOC), originally articulated by Paul and Margret Baltes (1990; Baltes, 1997) and developed further by Alexandra Freund (Freund & Baltes, 2000), Ralf Krampe (Krampe & Baltes, 2003), Michaela Riediger (Riediger, Li, & Lindenberger, in press), and others, successful development encompasses the selection of functional domains on which to focus one's resources, optimizing developmental potential (maximization of gains) and compensating for losses, thereby, ensuring the maintenance of functioning (minimization of losses).

The SOC model constitutes a general model of development defining universal processes of developmental regulation. These processes vary phenotypically depending on sociohistorical and cultural context, domain of functioning as well as on characteristics of the system or unit of interest (e.g., person, group, society). The metatheory of SOC needs to be embedded in a specific theoretical framework for applying it to various domains of functioning (e.g., identity formation and maintenance, social relations, athletic performance) and to different levels of analysis (e.g., societal, group, or individual level).

On a macroanalytical level, it is possible to apply SOC-related perspectives to questions of societal functioning. How do the American, German, and Japanese cultures differ in goals, ways to optimize, and strategies of compensation? This would be one example for a macroanalytic comparative study. An example of a microanalytic level approach to the study of SOC would be the investigation of cognitive and motor performance in dual-task conditions, and the way people of varying ages allocate resources differentially to memory and walking (K. Z. H. Li, Lindenberger, Freund, & Baltes, 2001).

(1) Selection

Throughout the lifespan, biological, social, and individual opportunities and constraints specify a range of alternative domains of functioning. From this large number of options, individuals, in collaboration with other forces, such as norms and parental expectations, select a subset on which to focus their resources. Selection of personal goals gives direction to development by focusing resources on specific life domains and by guiding behavior across situations and time. The function of selection is nicely illustrated by the saying "Those who follow every path, never reach any destination." Selectivity can also be an adaptive response to losses threatening one's goals. We call this loss-based selection, in contrast to elective selection. An example of loss-based selection is concentrating on one's most important goals (e.g., enjoying being with one's family) and giving up less important personal goals (e.g., cultural activities) when an illness constrains the level of energy one can devote to various activities.

(2) Optimization

To achieve higher levels of functioning, goal-relevant means, that is, means that are conducive to goal attainment, need to be acquired, refined, coordinated, and applied in the selected goal domains. We call the acquisition and orchestration of such means of goal attainment optimization. An example of optimization is practicing scales when starting to learn to play the piano. By practicing scales, one can acquire flexibility in finger movements and stroke techniques, both important skills for playing the piano. Of course, which means are best suited for achieving one's goals depends on the goal domain (e.g., sports, friendships), the social and cultural context providing opportunity structures that make certain means more accessible than others, and personal characteristics, such as age or gender. We also need to recognize that in most cases there are different pathways of optimization; consistent with the saying "There are many ways to Rome."

(3) Compensation

When transient or permanent losses or decline in goal-relevant means threaten one's level of functioning, it is necessary to invest resources into counteracting the losses in order to maintain a given level of functioning. We call the process of activating or finding such alternative means compensation. For instance, when knee problems do not allow going for walks any longer, using a wheelchair as a compensatory means of transportation can help to maintain one's routine of spending an hour in the park every day. As is true in the case of optimization, which means are best suited for compensating transient or permanent losses depends on the domain of functioning, the social and cultural context, and personal characteristics.

Recently, assumptions about SOC mechanisms have been formalized using differential equations to describe behavior in multiple-task settings in which the demands imposed by sum of all tasks exceeds the amount of available resources. We plan to intensify this line of work to study age differences in SOC mechanisms and arrive at SOC-based predictions of behavior.

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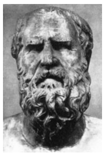
Research Project 1
Intra-Person Dynamics Across the Lifespan

All is flux; nothing stays still.
Heraclite, ca. 500 B.C.



Conceptual Overview

Behavioral development comprises both short-term variability and long-term change, and is embedded into cultural and neuronal contexts. The unifying theme of this project is to explore theories and research designs that articulate behavioral development across timescales, levels of analysis, and domains of functioning (see Figure 1 and Table 1). Conceptually, working toward this goal is facilitated by a dynamic systems view that seeks to identify the functional organization of behavioral change (Li, Huxhold, & Schmiedek, 2004; Lindenberger & von Oertzen, in press). Empirically, the emphasis on integration across timescales, domains, and levels requires a drastic increase in observation density within individuals (cf. Makeig, Debener, Onton, & Delorme, 2004; Thelen & Smith, 2004). In this vein, Cattell (1952) pled to gather multivariate observations not only within occasions across persons but also within persons across occasions. Between-person differences and within-person variations represent two complementary and mutually irreducible sources of information about developmental mechanisms whose similarities and differences are a matter of conceptual and empirical inquiry (Lövdén & Lindenberger, 2005; Nesselroade, 1991).

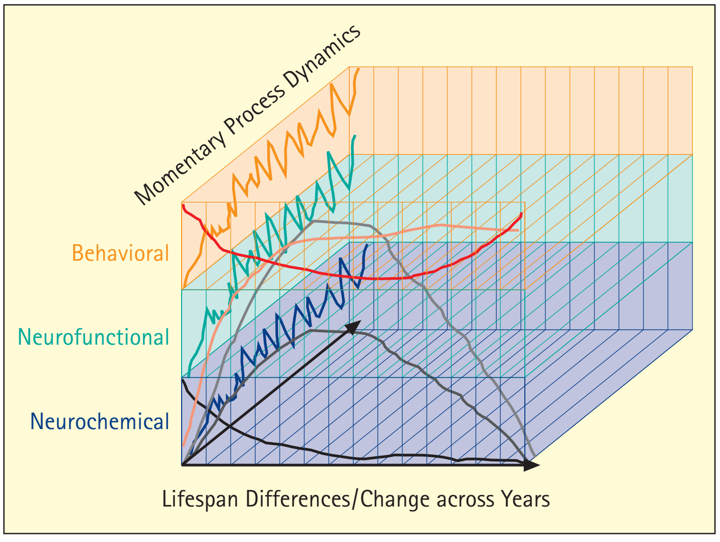


Figure 1. Long-term change and short-term variability in psychological functions. The Intra-Person Dynamics Project seeks to integrate the study of lifespan development across timescales and levels of analysis.

Types of Intra-Person Dynamics

Fiske (1955) distinguished between different types of intraindividual variations, some adaptive and some nonadaptive, that unfold with different degrees of reversibility over time and involve single or multiple functions. Specifically, short-term, relatively reversible variations in functioning need to be set apart from progressive, long-term, and relatively permanent developmental changes (Nesselroade, 1991). A main focus of this project is on describing and explaining lifespan age differences in relatively reversible variations that unfold within trials, training sessions, days, or weeks. Within this category of within-person variations, we functionally distinguish among

Table 1
Taxonomy of within-person variability in cognitive functioning across the lifespan

Timescale	Scope Variations in a single function (e.g., local, univariate)	Transformations in functional organization (e.g., global, multivariate)
Microgenetic (e.g., usually across trials, sessions, or weeks)	*Relatively reversible variations in one function* Examples: • processing fluctuation (processing lability or lack of processing robustness) • neural and behavioral plasticity (short-term learning potential) • within-task strategic diversity (richness of within-task behavioral repertoire) • adaptability/resilience to environmental perturbations • cyclic (e.g., state) variations in any specific function	*Relatively reversible variations in functional organization* Examples: • shifts in resource allocation, coordination, and compensatory behavior during multi-tasking • context-driven variations in mental set and functional organization (e.g., posture control with eyes open or closed) • situational choice and preference behavior
Ontogenetic (e.g., usually across months, years, or decades)	*Relatively permanent (e.g., cumulative, progressive) changes in one function* Examples: • physical growth • progressive (e.g., trait) changes in any specific cognitive function • long-term learning and skill acquisition	*Relatively permanent (e.g., cumulative, progressive) alterations in functional organization* Examples: • ability differentiation from adulthood to old age • ability dedifferentiation from childhood to early adulthood • corticogenesis and functional specification of brain areas during maturation and learning • functional reintegration of brain circuitry in old age

Note. This taxonomy is not meant to be exhaustive. For instance, societal sources of variability are not systematically considered. All listed forms of variability can be studied at behavioral and neuronal levels of analysis. Examples are drawn from both levels. A major challenge for lifespan psychology is to identify mechanisms that link local to global variations, microgenetic variations to ontogenetic change, and neuronal mechanisms to behavior. Theories that link neuronal mechanisms in a single function acting at a microgenetic timescale to global ontogenetic transformations in behavior are high in parsimony and explanatory power (adapted from Lindenberger & von Oertzen, in press; cf. Li, Huxhold, & Schmiedek, 2004).

fluctuation, plasticity, diversity, adaptability, and temporal coupling (for illustration of some of these aspects, see Figure 2). Indicators of each processing function can be observed at behavioral and neuronal levels. *Processing fluctuation,* or lack of processing robustness (e.g., Li, Aggen, Nesselroade, & Baltes, 2001; Li, Lindenberger, Hommel, Aschersleben, Prinz, & Baltes, 2004) reflects stochastic fluctuations around a modal response, and is often best observed near maximum levels of functioning. *Functional plasticity* refers to various forms of learning or adaptive changes, such as benefits from instruction, practice, and training (e.g., Baltes & Kliegl, 1992; Kliegl & Lindenberger, 1993; Singer, Lindenberger, & Baltes, 2003). *Functional diversity* refers to variations in responses to environmental demands, such as exploration of behavioral strategies during initial phases of complex skill acquisition

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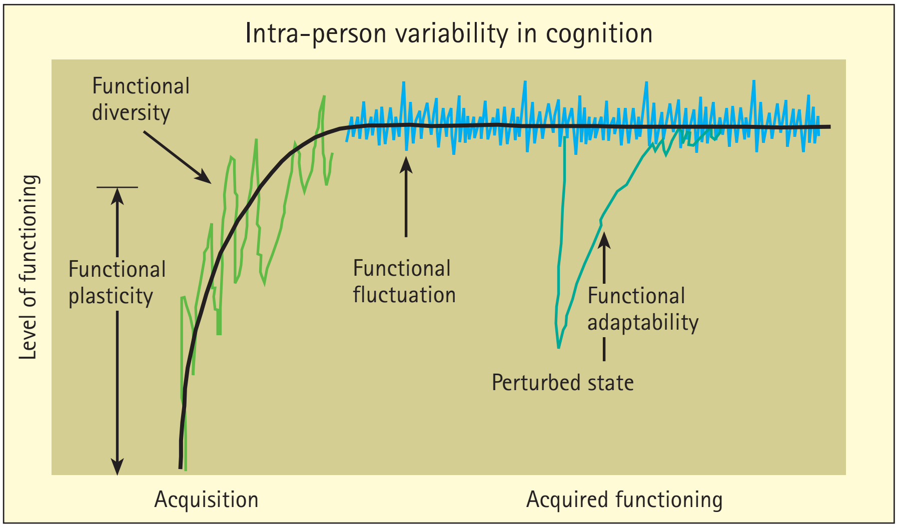

Figure 2. Types of intra-person variability in cognitive functioning (adapted from Li, Huxhold, & Schmiedek, 2004).

(e.g., Lautrey, 2002; Siegler, 1994). *Functional adaptability* indicates an individual's ability to regain earlier functional levels after perturbations arising from either internal processing fluctuations (e.g., attention slips) or changes in the external environment (e.g., more demanding tasks). Finally, *temporal coupling* refers to temporal associations between two or more forms of processing within or across domains of functioning, such as concurrent covariation, lead-lag relations, and synchronization.

Overview of Subprojects

The Intra-Person Dynamics Project was initiated in September 2002 and expanded in Spring 2004. Currently, it consists of three subprojects. The first investigates adult age differences in intra-person variability within and across various domains of psychological and sensorimotor functioning. The second investigates lifespan age differences in the plasticity and components of episodic learning and memory. The third subproject aims at systematic, age-comparative evaluations of inter-person and intra-person cognitive ability structures. Altogether, the project endorses a multilevel, multimethod approach that combines behavioral and neuronal observations with experimental, correlational, and computational methods.

Subproject I: Adult Age Differences in Intra-Person Dynamics Within and Across Psychological and Sensorimotor Domains of Functioning

The initial aim of this subproject is to document and compare adult age differences in intra-person dynamics within and across sensorimotor, cognitive, emotional, and motivational domains of functioning. Given the multi-dimensionality and multidirectionality of lifespan development with respect to functional domains and patterns of change (Baltes, Lindenberger, & Staudinger, in press), we expect that patterns of age differences in intra-person dynamics are not uniform across domains of functioning.

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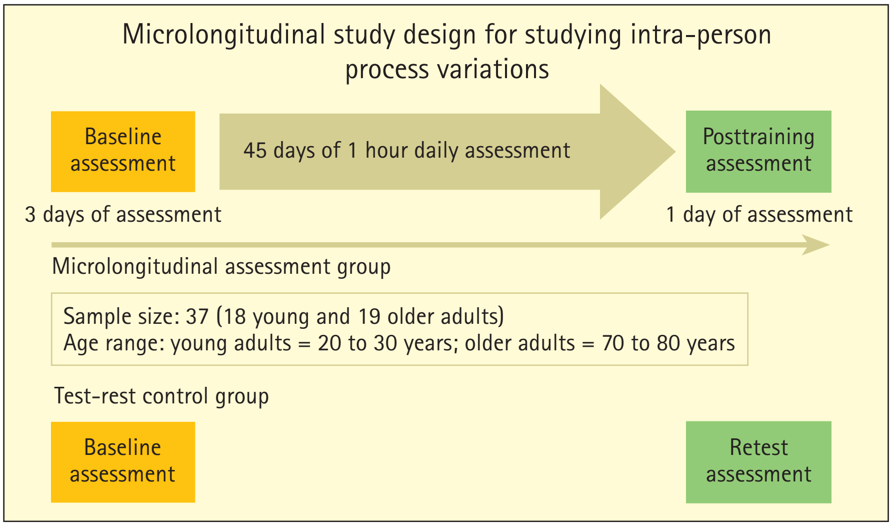

Figure 3. Microlongitudinal study design for investigating intra-person dynamics in multiple domains of functioning.

Using a microlongitudinal design that covered 45 daily measurement occasions (see Figure 3), we assessed daily fluctuations in postural control, spatial working memory, positive and negative affects, and task-specific motivation and performance appraisals in 18 young adults (20 to 30 years of age) and 19 older adults (70 to 80 years of age) across nine weeks. Overall, we observed substantial domain-related and person-related differences in within-person trajectories. Most individuals showed signs of learning (e.g., exponential performance functions) in spatial working memory and perceptual speed, with sizeable differences between individuals in learning rates and asymptotes. As for the sensorimotor domain, only about 60% of all individuals showed time-based improvements in postural control. Individual trajectories of emotional well-being and motivation also exhibited change over time, but there were substantial inter-individual and age-related differences.

As predicted, differences between younger and older adults in within-person fluctuations did not follow a unitary trend (see Figure 4). After controlling for trends, older adults exhibited more intra-person fluctuation in cognitive and sensorimotor functions than younger adults (Doctoral dissertation Oliver Huxhold). In contrast, older adults showed less intra-person fluctuation in emotion than younger adults (Dissertation Christina Röcke). The observed aging-related increments in within-person fluctuations in postural control and spatial working memory are in line with other recent findings, demonstrating greater processing fluctuation with advancing age in these domains of functioning (e.g., Hultsch et al., 2000; MacDonald et al., 2004, Rabbitt et al., 2001), and may point to senescent changes in brain integrity, such as attenuated neuromodulatory mechanisms (Bäckman & Farde, 2005; Li et al., 2001). In contrast, reductions in daily emotional fluctuations with age may point to increasingly more

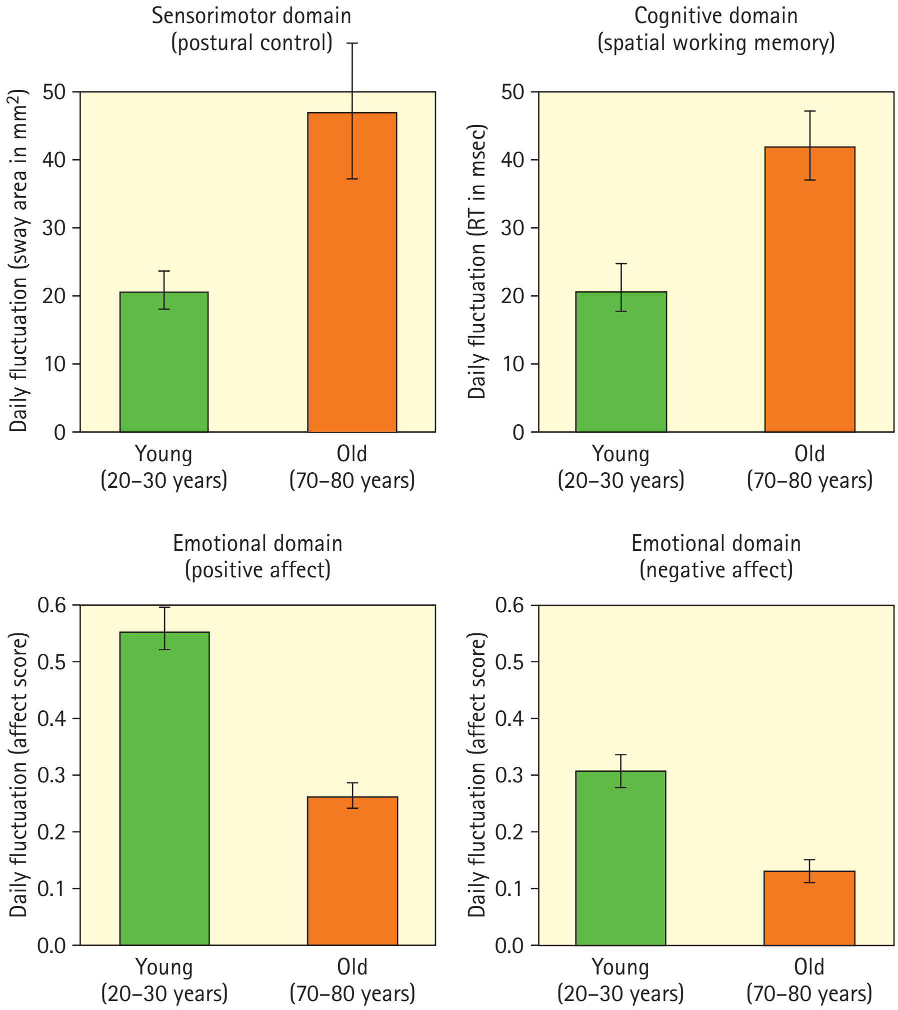

Figure 4. Patterns of age differences in intra-person daily fluctuations (indicated here as detrended residuals) are not uniform across different psychological domains. Whereas aging is related with increased process fluctuation in sensorimotor and cognitive processes (Dissertation Oliver Huxhold), it is related with decreased fluctuations in measures of subjective well-being (Dissertation Christina Röcke).

efficient emotional regulation (e.g., Gross et al., 1997; Lawton et al., 1992), to age differences in the selection of everyday life contexts (Baltes & Baltes, 1990; Carstensen, 1995), or both. Taken together, our findings from this first study underscore the multidimensionality and multidirectionality of age differences in intra-person dynamics.

Further analyses will focus on age differences in cross-domain temporal couplings. Methodologically, the influence of individual differences in intra-person fluctuations at lower levels of temporal aggregation (e.g., trial by trial) on estimates of cross-domain temporal couplings at higher levels of temporal aggregation (e.g., day by day) needs to be formally expressed and statistically controlled. Adult age differences in intra-person between-domain couplings will speak to the relative importance of age-associated causal mechanisms common to more than one domain of functioning (cf. Lindenberger & Baltes, 1994; Baltes & Lindenberger, 1997). Adult age differences in couplings between daily fluctuations in positive and negative affect and fluctuations in cognitive performance will provide insights into lifespan changes in the interaction between emotional and cognitive functions at the processing level.

Subproject II:
Lifespan Age Differences in Plasticity and Components of Episodic Learning and Memory

This subproject examines lifespan age differences in plasticity and components of episodic memory, and is partially funded by a research grant from the German Research Foundation (Deutsche Forschungsgemeinschaft, Forschergruppe 448, "Binding: Functional architecture, neuronal correlates, and ontogeny"). It pursues two interrelated goals: (a) to investigate age differences in intra-person plasticity of episodic memory from middle childhood to later adulthood; (b) to estimate the relative contribution of strategic and associative components to lifespan differences in episodic memory.

In a first training study conducted at Saarland University in 2003, 23 younger children (9 to 10 years of age), 27 older children (11 to 12), 29 younger adults (20 to 25), and 29 older adults (65 to 78 years) were instructed and trained in a simplified variant of the Method of Loci, an imagery-based mnemonic strategy (Baltes, Kliegl, & Smith, 1990; Kliegl & Lindenberger, 1993). All age groups benefited from mnemonic training (Figure 5). At the same time, substantial age differences in gains were observed as a function of instruction versus training practice. Older adults showed considerable instruction-related performance gains (baseline reserve plasticity), but did not profit much from further training and practice (developmental reserve plasticity). In contrast, younger children initially showed smaller instruction-related performance gains, but considerably larger practice-related gains than older adults. The resulting memory plasticity advantage of middle childhood over late adulthood provides direct empirical support for central assumptions about lifespan changes in behavioral plasticity (Dissertation Yvonne

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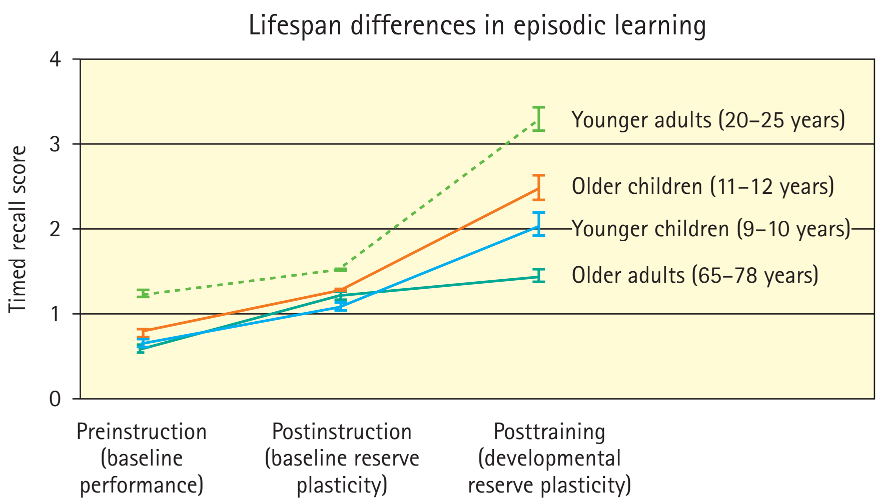

Figure 5. Lifespan age differences in episodic associative learning. Individuals in all age groups showed substantial memory plasticity. Whereas older adults showed a greater extent of baseline reserve plasticity after mnemonic instruction, younger children showed a greater extent of developmental reserve plasticity after mnemonic training (Dissertation Brehmer; Brehmer, Li, Müller, von Oertzen, & Lindenberger, in prep.).

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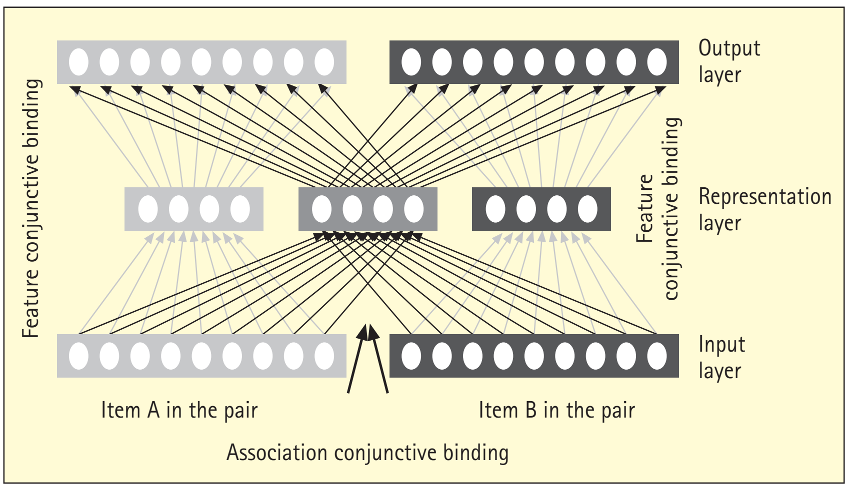
Brehmer). To examine lifespan age differences in maintenance of mnemonic skill (e.g., Neely & Bäckman, 1993), a one-year follow-up study has been carried out in 2004. Also, initial analyses of EEG data are currently underway. The general rationale of these analyses is to identify EEG patterns in the frequency domain that optimally separate recalled words from not recalled words at three nested levels of analysis: within individuals, between individuals within age groups, and between age groups.

Strategic and Associative Components of Lifespan Differences in Episodic Memory

In Fall 2004, a new series of experiments has been planned to provide a more process-oriented (mechanistic) explanation for lifespan differences in episodic memory, such as the relative magnitude of baseline and developmental reserves plasticity observed in the first study (see Figure 5). In this context, we posit two different, but closely intertwined, components of episodic memory performance: strategic and associative. In terms of cognitive processes, the strategic component refers to the selection, organization, and elaboration of episodic features during encoding and retrieval. In contrast, the associative component refers to mechanisms that bind features into a coherent memory representation (trace). Due to the late maturation of prefrontal regions and associated neuronal pathways, we assume that the strategic component of learning and memory is less efficient in middle childhood than in early and young adulthood. In contrast, the associative component, which primarily involves mediotemporal structures, should be fully functional in middle childhood, so that differences to younger adults in this component should be small. With respect to older adults, we expect impairments in both strategic and associative components relative to younger adults, reflecting alterations senescent changes in both prefrontal and mediotemporal regions of the brain. A new series of experiments will test these predic-

Figure 6. Schematic diagram of a feature association conjunctive binding model for studying adult age differences in associative binding deficit (adapted from Li, Naveh-Benjamin, & Lindenberger, in press).



tions using a paired-associates recognition memory paradigm (cf. Castel & Craik, 2003; Naveh-Benjamin, 2000; Dissertations Yee Lee Shing and Markus Werkle-Bergner). At the same time, we have begun to expand our connectionist modeling to simulate lifespan differences in strategic and associative memory components (see Figure 6; Li & Lindenberger, in press; Li, Naveh-Benjamin, & Lindenberger, in press; Zimmer, Mecklinger, & Lindenberger, in press).

Subproject III:
Comparing and Contrasting Intra-Person Variability With Inter-Person Differences

The specific goal of this subproject, which started in Spring 2004, is to explore differences and commonalities between covariance structures of intellectual abilities measured either across individuals at a given occasion or across occasions within a given individual. Most of the existing research on intellectual abilities assumes that covariance structures based on interindividual differences generalize to intra-person structures. For instance, ability factors based on interindividual differences are supposed to reflect unitary ability constructs at the intra-person level, and intercorrelations among such factors are assumed to reflect relations among underlying processes or resources at the intra-person level. Methodologically, differences between intra-person and inter-person structures are perfectly possible (e.g., Borsboom, Mellenbergh, & van Heerden, 2003; Lindenberger, & von Oertzen, in press; Molenaar, Huizenga, & Nesselroade, 2003). Conceptually, the malleability of functional organization at both behavioral and neuronal levels and the diversity of developmental trajectories and life experiences (Li & Lindenberger, 2002) render any strict congruence between intra-person and inter-person structures unlikely. What is needed, then, is to examine: (a) the degree of convergence between intra- and inter-person structures, and the extent to which this convergence differs by age; (b) the degree of convergence among different intra-person structures. To date, no studies with the multivariate measurements of cognitive performance and sufficiently high numbers of observations and individuals have been conducted to address these issues empirically. To conduct such a study, we currently are assembling a battery of cognitive tasks that are amenable to repeated testing and that represent well-established cognitive constructs of psychometric research.

Principal Investigators

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Research Project 2
Sensorimotor-Cognitive Couplings

This project investigates lifespan changes in interactions between sensorimotor and cognitive aspects of behavior (K. Z. H. Li & Lindenberger, 2002). Everyday life often requires integration of multiple sensory inputs and concurrent coordination of sensorimotor and cognitive demands. Examples are walking while trying to memorize a shopping list, maintaining one's balance on a bus while trying to read an advertisement, or trying to remember the way to a friend's house while driving in the hectic morning traffic. How do individuals of different ages adapt to these multiple demands and their changes across situational contexts? Everyday observation further suggests that older adults, and young children, need to invest more attention into sensorimotor aspects of their behavior than teenagers and young adults. For instance, when facing an obstacle on a narrow path, older adults may tend to stop talking and resume their conversations after the obstacle has been overcome, whereas the same obstacle will affect younger adults' conversation to a lesser extent.

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The focus of this project is on lifespan changes in resource allocation in multiple-task settings that have a high degree of everyday validity, such as walking while memorizing. The project makes use of three different experimental paradigms: (a) walking tracks that allow for the assessment of walking accuracy, (b) balance machines permitting dynamic assessment of posture control (posturography), and (c) a virtual reality lab equipped with a treadmill to measure spatial navigation performance under varying conditions of sensorimotor support.

Dual-Task Costs in the Domain of Walking

Two earlier studies from our lab demonstrated that older adults invest considerable cognitive resources to compensate for the decreased efficiencies of their sensorimotor functions. Lindenberger, Marsiske, and Baltes (2000) had participants from three age groups walk different tracks while memorizing word lists. They found that speed and accuracy of walking were reduced when participants had to simultaneously walk and memorize, particularly in older adults. K. Z. H. Li, Lindenberger, Freund, and Baltes (2001) systematically combined sensorimotor tasks of varying difficulties with a cognitively demanding memorization task and offered compensatory external aids (a handrail to optimize walking and a button-box that delayed the presentation of auditory stimuli). Whereas young adults optimized their memorization performances, older adults focused on the optimization of their walking by more frequently using the handrail. Thus, older adults selected walking efficiency over memory efficiency when their cognitive resources were challenged.

In a recently completed study, we (Krampe, Schäfer, Lindenberger, & Baltes, in prep.) investigated resource allocation in children (9 or

11 years old) and adults (young and older). To this end we used the walking track in combination with a semantic fluency task (Figure 1). In line with our earlier results, we found that young adults maintain their level of performance in the cognitive task and "accept" reductions in walking speed. Children, however, showed higher costs in walking than young adults, and 9-year-olds also demonstrated considerable costs in the cognitive task. These findings illustrate that the age-differential "protection" of gait and balance is not a result of the amount of available cognitive resources alone. Rather, ecological considerations are important: The consequences of withdrawing attention from gait or balance are far more serious for older adults than for young adults or children.

Figure 1. Dual-task experiment with walking track. Participants (9- or 11-year-old children, young and older adults) walk along a narrow track at their maximum speeds while simultaneously performing a cognitive task, for instance, memorization of a list of words presented over wireless headphones or generating exemplars for semantic categories like animals.

Dual-Task Costs in the Domain of Balance

Using dynamic posturography, two recently completed studies investigated balance performance while standing. Participants stood on a platform that can tilt at various angular velocities (Figure 2). The platform contains sensors that measure participants' stability (i.e., the distribution of their weights) at any given point in time. Bondar, Krampe, and Baltes (in prep.) had young and older adults perform choice reaction time tasks while maintaining upright stance despite unpredictable perturbations during trials. Older adults were found to have larger dual-task costs than younger adults. At the same time, they showed increased neglect of the cognitive task when the experimentally induced perturbations were increased. In specific experimental conditions, participants were asked to emphasize performance in either the cognitive task, the balance task, or to place equal emphasis on both conditions. Older and young adults revealed similar flexibilities in resource allocation in the cognitive task. During trials with stronger perturbations, however, only young, but not older, adults were capable of flexible allocation of resources to stance maintenance. Again, these results can be interpreted as differences in overall resources and as older adults' specific selection of attentional emphasis on walking or maintaining a stable posture over simultaneous cognitive

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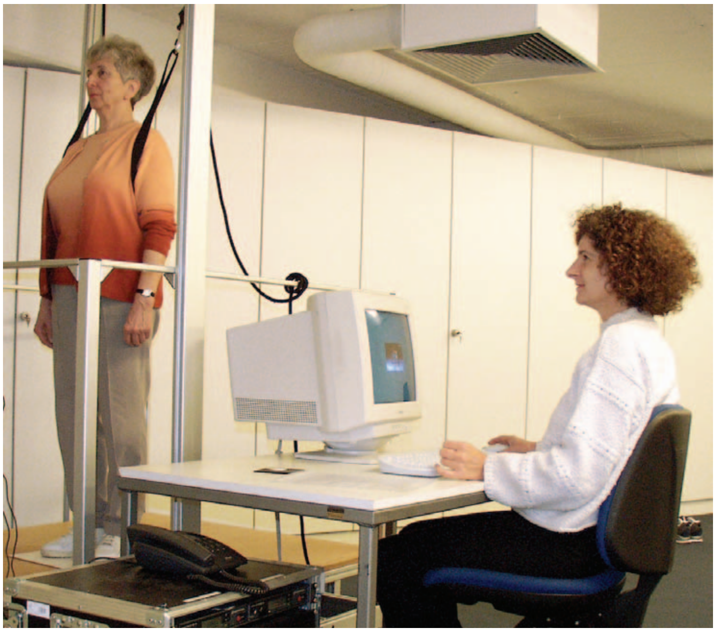

Figure 2. Dynamic posturography. Balance performance on the moving platform can be assessed while participants simultaneously perform a cognitive task.

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tasks. In older age, sensorimotor functions require more and more cognitive resources. Because of their allocation to the sensorimotor domain, these cognitive resources are then no longer available for competing mental activities. Our results highlight the differential ecological relevance of tasks for young and older adults and its effects on resource allocation: Walking or maintaining balance is more critical for older than for young adults. Consequentially, older adults prioritize sensorimotor over cognitive functioning, especially when tested at their limits.

The findings by Bondar, Krampe, and Baltes imply that the observed prioritization in older adults reflects overlearned response tendencies resulting from long-term everyday experiences. This assumption was further supported in another study using the balance-cognition dual-task paradigm. Rapp, Krampe, and Baltes studied young and older adults along with a group that is assumed to have deficits in attentional control or resource allocation, Alzheimer patients. Older adults showed a reliable *reduction* in sensorimotor dual-task costs when conditions of stable and moving platforms were compared, again suggesting that they protected their balance at the cost of cognitive performance. Alzheimer patients' dual-task costs were significantly increased relative to healthy age-matched individuals. However, the Alzheimer group showed the same prioritization when limits were challenged: When the platform was moving, Alzheimer patients invested most of their cognitive resources into the sensorimotor task, thereby maintaining almost the same stability as under single-task conditions (Figure 3). A subsequent inclusion of another group of nondemented older adults that was more similar to the Alzheimer patients with respect to their cognitive status (fluid intelligence) suggested that the exaggerated Alzheimer pattern was specific to dementia. These findings demonstrate how Alzheimer patients "know how to survive" in situations where memory and motor behavior are required at the same time.

To further chart the terrain of sensorimotor–cognitive couplings across the lifespan, we conducted a large-scale study assessing postural stability, gait, and performances in standard psychometric measures of intelligence with 300 participants (age range 7 to 80 years). We used latent structure modeling approaches to

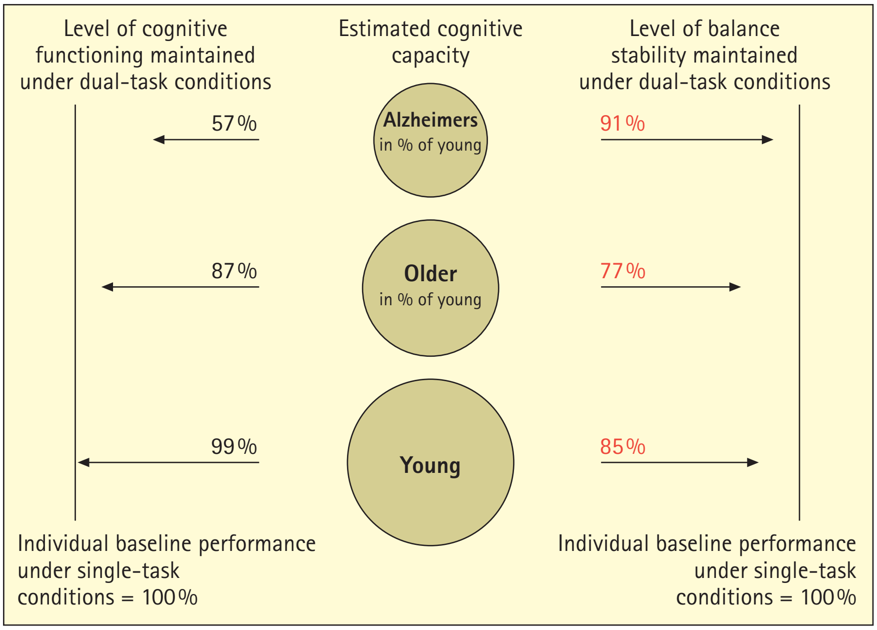


Figure 3. Resource investment into cognitive and bodily functions under dual-task conditions. Alzheimer patients exhibit smaller levels of cognitive functioning when their balance is challenged through the moving platform.

identify the correlations between these different capacities and their changes across the lifespan. These data are also used for the development of a mathematical model of postural control in different age groups that is based on random walk and diffusion concepts.

Sensorimotor Aspects of Spatial Navigation

The major aim of this part of the project is to explore the old-age quandary between increasing control demands of sensorimotor functioning and decreasing efficiency of relevant control operations in the domain of spatial navigation. A virtual environment maze-learning paradigm with a walking component was developed for this purpose. A scenery, designed to give participants the impression of walking through an art museum is projected in front of a treadmill. The movement of the treadmill is synchronized to the visual flow of the virtual environment such that participants have the impression of actually walking through the virtual environment. The task for participants might be, for example, to find and remember the way from the entrance of the museum to the bistro. Figure 4 shows a prototype of the experimental paradigm. As of December 2004, the MPI laboratory features an advanced motion capture system, integrated synchronized assessment of EEG and EMG components, improved conditions for virtual environment rendering, and an advanced treadmill allowing for a wider range of movement.
Figure 5 shows captures of different motions that have been taken in this laboratory. To visualize the participant's movement (e.g., while walking) markers reflecting infrared light are attached to the participant's body. In turn, cameras capture the position of the markers, and the

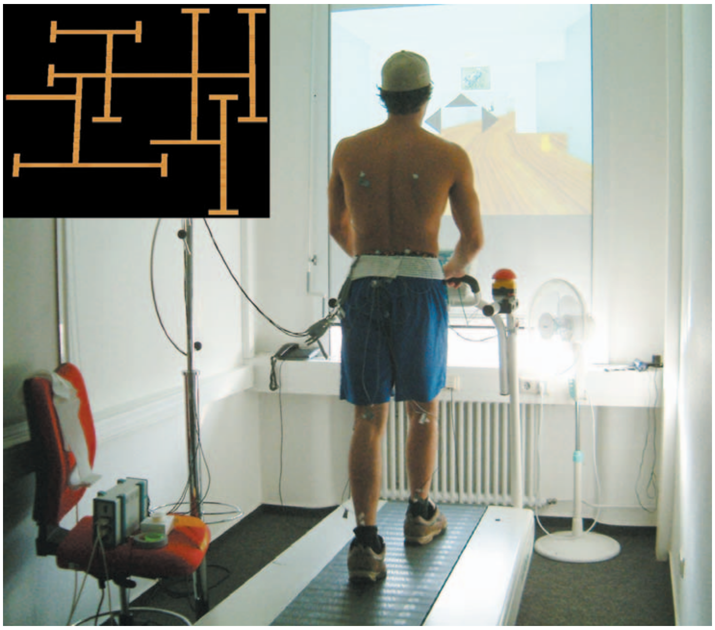
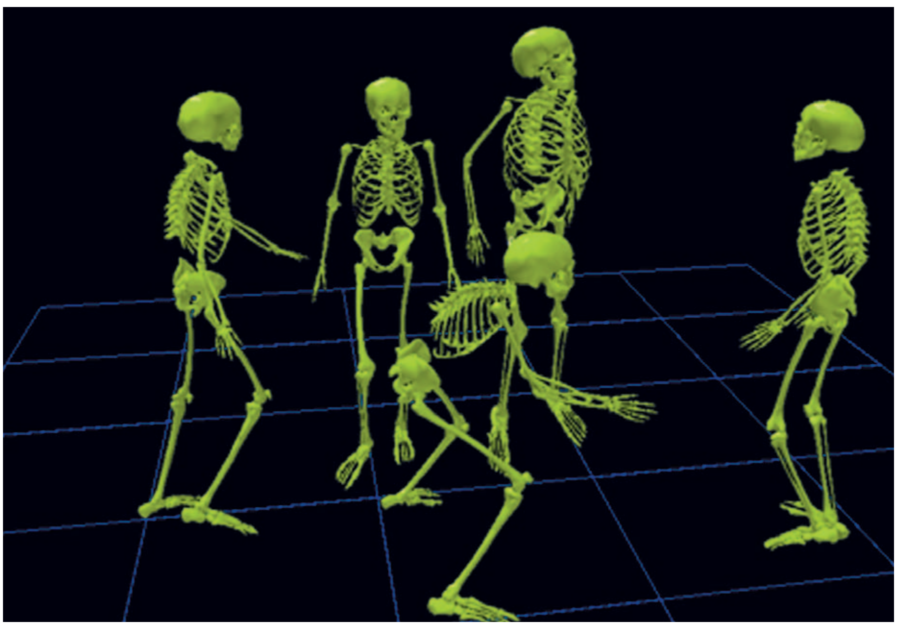


Figure 4. Spatial navigation in a virtual art museum. Participants walk on the treadmill while navigating to goals in the virtual environment. Older adults navigation performance is improved by walking support (holding on to the handrail).

positions of the markers are post-processed offline according to biomechanical models. This procedure allows for visualization of the participant's movements and further statistical analyses of important parameters. In Figure 5, a single participant has performed different typical motions (e.g., walking, dancing, playing tennis), and processed motion captures of these movements are displayed simultaneously. This system will play a major role in examining how sensorimotor functions interact with cognition as a function of age.

The first study (Lövdén, Schellenbach, Grossman-Hütter, Krüger, & Lindenberger, 2004), still conducted at Saarland University, tested our fundamental hypothesis that aging-induced cognitive permeation of sensorimotor functions contributes to adult age differences in spatial navigation performance. Sixteen 20- to 30-year-old and sixteen 60- to 70-year-old men were required to

Figure 5. Processed motion captures of an individual performing a variety of different movements. The position of markers attached on the participant's body is captured by cameras and postprocessed according to biomechanical models to arrive at dynamic visualization of the participant's movements.



find and remember the way to the bistro in museums under conditions of walking with support (holding on to a handrail) or without support until they reached perfect performance. Walking support attenuated age-related decrements in navigational learning, and walking with navigation load increased older adults', but not younger adults', trunk-angle variability. Thus, walking demands influenced the navigation performance of older, but not younger adults.

Future Perspectives

In our future work, we will examine the effects of assistive technology on spatial navigation. For instance, we hypothesize that providing older adults with walking support enhances their ability to find and remember the way to a place in the environment. We will also examine lifespan age differences in gait patterns as a function of cognitive load, and investigate the plasticity of spatial navigation in old age at neuronal and behavioral levels of analysis (Lindenberger & Lövdén, in press).

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Research Project 3
Berlin Aging Study (BASE): Trends and Profiles of Psychological Aging

For lifespan researchers, the period of old and very old age is a new and exciting area of study. During the 20th century, average life expectancy nearly doubled. More and more individuals in current cohorts of older individuals experience additional years of life between the ages of 70 and 100+. What do these added years mean in terms of levels of functioning and life quality for most people? Are there constraints on aging successfully in the last years of life? Compared to early phases of the lifespan, relatively little is known about advanced old age.

Since 1989, members of the Center of Lifespan Psychology have investigated age- and death-related changes in psychological functioning from age 70 to 100+ in the context of the Berlin Aging Study (Mayer & Baltes, 1999; Baltes & Mayer, 1999; 2001; Lövdén, Ghisletta, & Lindenberger, 2004; Smith & Delius, 2003; Smith, Maas, Mayer, Helmchen, Steinhagen-Thiessen, & Baltes, 2002; see textbox for description of BASE). This multidisciplinary study is one of the few projects worldwide that includes extensive data on a heterogeneous sample of old and very old individuals.

At present, longitudinal data in BASE are available over 6 measurement occasions, spanning more than 12 years. The last follow-up of the Psychology Battery was collected in 2004. In addition to documenting the diversity of longitudinal patterns of change, this design feature has served to highlight the complex implications of sample attrition for the interpretation of findings about the oldest old. At the last assessment in 2004, for example, 80 % of the baseline sample of 516 were deceased. In general, participants in the various BASE longitudinal samples (followed over 4, 6, and 8 years) have been a positive selection of the initial cross-sectional sample in terms of physical and functional health, social status, cognitive functioning, openness to new experiences, outgoingness (extraversion), age, and distance from death (Lindenberger, Singer, & Baltes, 2002).

In the period 2003 to 2004, our research has focused on mapping individual differences and age-related changes in intellectual functioning (e.g., Singer, Verhaeghen, Ghisletta, Lindenberger, & Baltes, 2003), mechanisms underlying differential aging (e.g., Smith & Gerstorf, 2004; Gerstorf, 2004), and predictors of well-being in the young old and oldest old (e.g., Issacowitz & Smith, 2003). In addition, we also examined cross-domain associations in intraindividual change patterns.

Changes in Intellectual Functioning From Age 70 to 100

Lövdén, Ghisletta, and Lindenberger (2004) summarized 10 years of cognitive research in BASE (i.e., 1993–2003), focusing on five related research themes: (a) longitudinal selectivity; (b) cross-sectional and

Overview of the Berlin Aging Study (BASE)

The multidisciplinary Berlin Aging Study (BASE), directed by Paul B. Baltes and Karl Ulrich Mayer, was initiated in 1989 under the sponsorship of the former West Berlin Academy of Sciences and Technology and its Committee on Age and Societal Development. Subsequently, and in connection with the reestablishment of the Prussian Academy, the study came under the auspices of the Berlin-Brandenburg Academy of Sciences.

As of 2004, the study involves six measurement occasions spaced over 14 years. In addition, subsamples have been recruited for intensive study. The distinguishing features of BASE include (1) a focus on the very old (70–100+ years), (2) a locally representative sample, stratified by age and sex, and (3) a broad-based interdisciplinarity (involving two research groups from the Free University of Berlin, Internal Medicine and Psychiatry, and two from this Institute, Sociology and Psychology). In addition to discipline-specific topics, four integrative theoretical orientations guide the study: (1) differential aging, (2) continuity versus discontinuity of aging, (3) range and limits of plasticity and reserve capacity, and (4) aging as a systemic phenomenon.

The initial focus of BASE (1990–1993) was to obtain an age-by-sex stratified heterogeneous sample of 70- to 100+-year-olds who completed a 14-session Intensive Protocol (involving detailed measures from the four disciplines). 516 men and women from the western districts of Berlin participated. Five longitudinal follow-ups of the survivors from this initial sample involving different amounts of assessment have been completed at approximately 2-yearly intervals. A single-session multidisciplinary assessment was collected in 1993–1994 ($N = 361$), reduced versions of the Intensive Protocol (six sessions) were collected in the periods 1995–1996 ($N = 206$) and 1997–1998 ($N = 132$), and a repeat of parts of the Psychology Battery together with multidisciplinary outcome variables (e.g., screening for dementia, assessment of well-being) in 2000 ($N = 82$) and 2004 ($N = 50$). In addition, we also follow the mortality of the entire BASE sample.

The initial sample of 516 individuals formed the basis of the cross-sectional analyses reported in a German monograph first published in 1996 (Mayer & Baltes, 1996, 1999), in a featured section of *Psychology and Aging* (1997), and an English monograph published with Cambridge University Press (Baltes & Mayer, 1999, 2000). Six papers reporting two-wave longitudinal findings were published in November 2002 in a Special Section of the *Journals of Gerontology: Psychological Sciences (57B,* P471–P571). Specific interests of the Psychology Unit of BASE include: issues of sample selectivity and representativeness, cognitive aging, subgroup profiles of psychological functioning, the Fourth Age, gender differences, mortality prediction, self-related change, well-being, and models of successful aging, such as selective optimization with compensation.

Doctoral Training Program (Graduiertenkolleg) in Neuropsychiatry and Psychology of Aging Jointly With the Free University of Berlin

From1998 to 2004, the research findings and data of BASE provided a primary foundation for a DFG-funded graduate research training program (Graduiertenkolleg). The focus of this program was on the "Neuropsychiatry and Psychology of Old Age." Initiated by the late Margret M. Baltes, the doctoral training program was codirected by Paul B. Baltes. Other psychologists in the Steering Committee were Jacqui Smith and Ralf Schwarzer (Free University of Berlin). In the period 2003–2004, the program included 15 fellows.

See pp. 27–28 for further information.

longitudinal age gradients of intellectual functioning; (c) cognitive ability dedifferentiation in old age; (d) exploring the link between intellectual and sensory domains; and (e) limits to cognitive plasticity in old age. Here, we highlight key findings from the 2002 to 2004 period.

The cross-sectional pattern of decline across adulthood for the fluid mechanics (e.g., processing speed) accompanied by maintenance or increase in the crystallized pragmatics (e.g., verbal knowledge) constitutes a classic aging pattern of adult intellectual development. Initial findings from BASE extended this pattern by revealing negative cross-sectional associations between verbal knowledge and age within, but not before,

www.base-berlin.mpg.de

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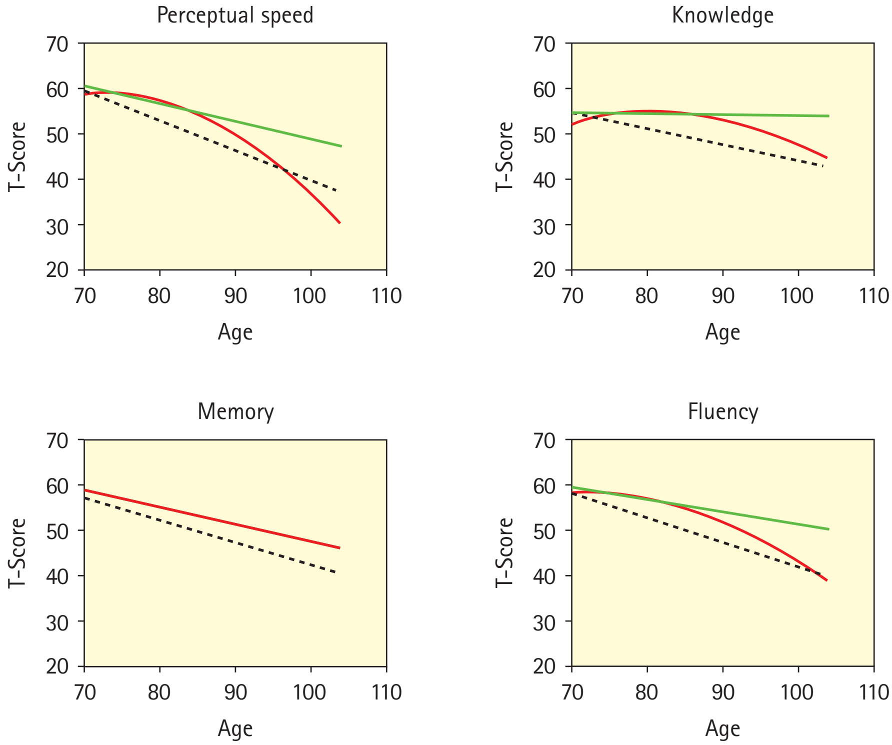
Figure 1. Cognitive change in old age (BASE). The short-dashed lines represent the cross-sectional age gradients as observed in the initial assessment of the total sample (*N* = 516). The green lines represent the cross-sectional age gradients as observed in the initial assessment of the 6-year longitudinal sample (*n* = 132). The red lines represent the estimated longitudinal change gradients over the 6-year interval in the longitudinal sample. Individuals up to age 90 show longitudinal stability in tests of knowledge despite declines in measures of perceptual speed, memory, and fluency (adapted from Singer et al., 2003).



old and very old age (Baltes & Lindenberger, 1997). We further extended these findings by reporting longitudinal age gradients while examining aspects of longitudinal selectivity. Specifically, Singer et al. (2003) reported latent growth curve age gradients for processing speed, memory, verbal fluency, and knowledge as a function of three subsamples: cross-sectional age gradients for the total initial sample (*N* = 516) including participants suffering from late-life cognition-associated health disorders; cross-sectional age gradients for the positively selected individuals (*n* = 132) that subsequently survived and participated in the repeated measurement occasions; and combined cross-sectional and longitudinal information for the longitudinal sample. Figure 1 displays these age gradients.

If we initially consider the cross-sectional gradient of the total sample (short-dashed line), it is evident that negative gradients prevail in all four cognitive measures. In contrast, the cross-sectional gradients describing the positively selected longitudinal sample (green line) are more diverse: Knowledge remains stable whereas processing speed, fluency, and memory decreases. In other words, decline in the fluid mechanics may be normatively age-related, whereas decline in the crystallized pragmatics may also be associated with late-life cognition-associated health disorders. The longitudinal gradient (red line) is consistent with this conclusion. In very old age (> 90 years) negative gradients are evident for all the four cognitive abilities.

Initial cross-sectional analyses in BASE (Baltes & Lindenberger, 1997) supported the dedifferentiation hypothesis, asserting that the functional organization of intellectual abilities undergoes compression (dedifferentiation) in old age. Framed in terms of the distinction between the fluid mechanics and crystallized pragmatics of cognition, dedifferentiation is hypothesized to emanate and form old-age decrements in pragmatic abilities that are induced by mechanic decline. To evaluate the validity of this hypothesis, Ghisletta and Lindenberger (2003) applied a lead-lag structural equation modeling method to combined longitudinal and cross-sectional data. Processing speed and knowledge were used to index the mechanics and the pragmatics, respectively. The results showed that processing speed was the leader and knowledge was the lagger within this system of variables; that is, processing speed at t–1 time exerted a substantially stronger influence on change in knowledge from t–1 to t than knowledge at t–1 did on subsequent change in processing speed. Thus, the directional dedifferentiation hypothesis was confirmed.

The potential range of plasticity of functioning in very old age, especially in the capacity to learn and apply new memory strategies, has been addressed by Singer, Lindenberger, and Baltes (2003) on a subsample of the oldest old participating in BASE. Using a cognitive training paradigm and instruction in a memory technique (the Method of Loci), participants aged 70 to 100 years evinced little potential for the new learning of a complex cognitive skill. Thus, the quantity and quality of cognitive plasticity show a sizeable loss in very old age, compared to younger age groups.

Currently, the role played by health in the maintenance of cognitive functioning in old age constitutes an emerging area of interest within BASE. Analyses of BASE data have related performance to cardiovascular and metabolic disease and various risk factors (e.g., smoking). Verhaeghen, Borchelt, and Smith (2003) found that five diagnoses were negatively correlated with cognition: congestive heart failure, stroke, coronary heart disease, myocardial infarction, and diabetes mellitus. The presence of one or more of these diagnoses was linked to lower performance in general, but there was no differential cognitive decline over 4 years. This suggests that the impact of these diseases on cognitive decline in very old age may be smaller than in younger adults because the disease process adds little to the cumulative changes in brain physiology that have occurred over the course of a very long life.

Another currently important area of investigation in BASE is the relationship between lifestyle factors, such as social participation and cognitive decline. Though the general public have embraced the notion that being socially, mentally, and physically active in old age protects against cognitive decline, several studies have delivered mixed support and underscored that the opposite might also hold: High cognitive functioning in old age might increase the possibility of maintaining an engaged and active lifestyle. Lövdén, Ghisletta, and Lindenberger (in press) approached this conundrum by apply-

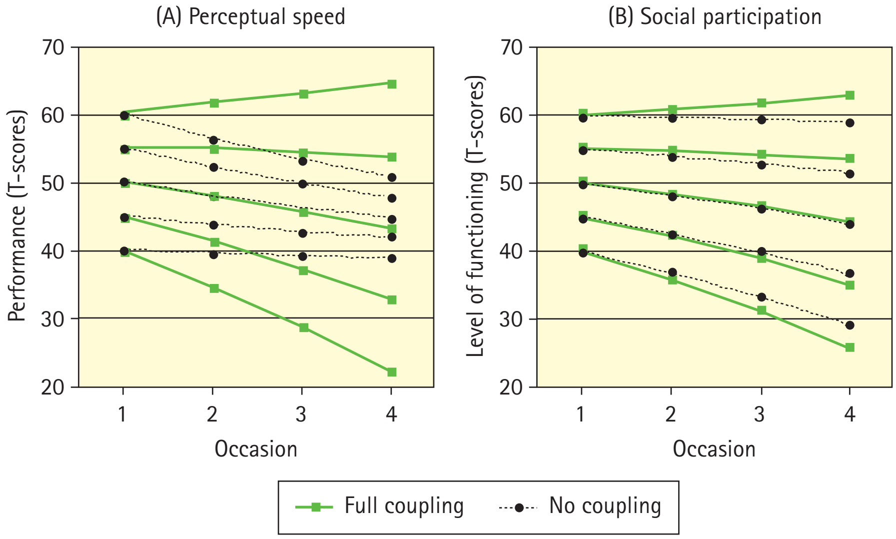


Figure 2. Social participation attenuates decline in perceptual speed in old and very old age. Means for perceptual speed (A) and social participation (B) from a model (full coupling; green lines) allowing dynamic lead-lag relations and from a model not allowing dynamic lead-lag associations (no coupling; dashed lines) between social participation and perceptual speed. The means are plotted as a function of time and varied initial (occasion 1) sample means (40, 45, 50, 55, 60). The figures show that allowing for lead-lag coupling between the two variables dramatically changes the implied developmental pattern for perceptual speed, but that this is not the case for social participation, suggesting that social participation drives decline in perceptual speed in old and very old age.

ing a structural equation model for testing lead-lag hypotheses (see also Ghisletta & Lindenberger, 2003) to three-occasion longitudinal data of social participation and perceptual speed in BASE. Results revealed that, after statistically controlling for age and sociobiographical status, prior scores of social participation influenced subsequent changes in perceptual speed, while the opposite did not hold (see Figure 2). Results support the hypothesis that an engaged and active lifestyle in old and very old age may alleviate cognitive decline.

Change and Stability in Self and Well-Being in Very Old Age

Findings in areas of psychological functioning other than intelligence, such as motivational aspects of the self (e.g., control beliefs, future-oriented goals) and overall subjective well-being (e.g., life satisfaction, a sense of happiness and contentment), indicate less decline in functionality, at least among the young old and positive selected oldest old individuals (Smith, 2003; Smith & Gerstorf, 2004). Self-related functioning may be more resilient against decline than is true for the cognitive system. It is generally expected that regulatory processes operate to protect or “immunize” the self against a loss of efficacy and well-being, even in conditions of poor health and chronic impairment. For example, individuals adjust their aspiration levels and comparison targets so as to achieve and main-

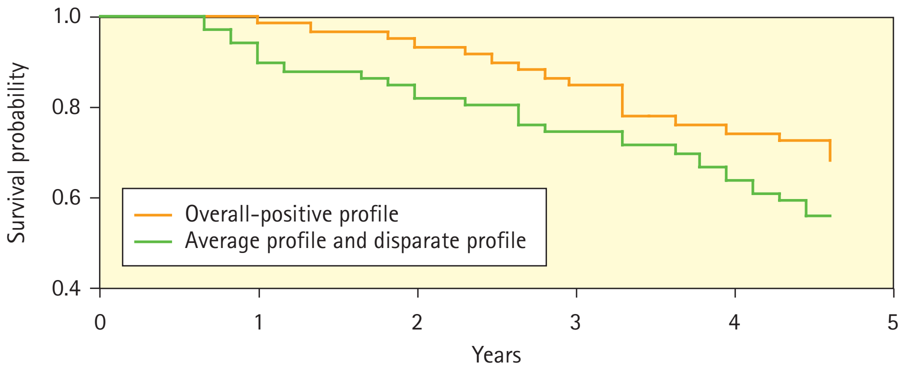


Figure 3. Profile subgroups were identified in the 6-year longitudinal BASE sample by using cluster analysis of baseline scores across 11 psychological dimensions (cognition, personality, and social integration): The desirable profile subgroup (overall-positive profile) lived longer over a 4-year period than both less desirable profiles (average profile and disparate profile) (adapted from Gerstorf, 2004).

tain a sense of control over their life. These psychological processes help to explain the seemingly paradoxical observation that, after a period of adjustment, individuals report satisfaction even in contexts of chronic stress.

To the extent that older individuals become physically dependent on others and experience accumulated chronic health and life strains, their sense of well-being is compromised. In particular, we observed a reduction in the potential to experience the positive side of life (Baltes & Smith, 2003; Smith, 2003). Although the majority of BASE participants were typically satisfied with their present life conditions, those in the Third Age (70 to 84 years) reported significantly higher positive well-being and higher satisfaction with life in general, compared with those in the Fourth Age (85 to 100+ years). A large portion of individual differences in well-being was accounted for by physical illness and functional impairment (e.g., vision, hearing, mobility, strength). On average, reported satisfaction with aging, life satisfaction, and experience of positive emotions decreased after age 80.

Profiles of Psychological Functioning in the Young Old and Oldest Old

Psychologically speaking, the chronic life stressors associated with advanced old age represent a context that appear to "test the limits" of psychological resilience and adaptation and may contribute to systemic breakdown and death (Baltes & Smith, 2003). This proposal was examined in BASE in several ways. On the one hand, we analyzed age-related changes in functional level in different domains, and examine whether different rates and correlates of change characterize the young old and the oldest old (Smith & Gerstorf, 2004). In addition, we used cluster analysis to identify subgroups with functional psychological profiles indicative of distress and systemic breakdown (Gerstorf, 2004; see Figure 3).

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Research Project 4
Selection, Optimization, and Compensation (SOC): Regulation of Goals and Preferences in Lifespan Development

Scientific Investigators

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Tra dire e fare
C'e di mezzo il mare.
(Between saying and doing is the sea.)
Italian proverb

Understanding human development requires theories of dynamic self-regulation that place goal-directed action and preference behavior in the context of biological and social constraints and opportunities. How are developmental goals and preferences construed, pursued, coordinated within and between individuals, and reshaped or abandoned in the face of limited internal and external resources? Which behavioral features and regulatory patterns separate positive or subjectively desired from negative or unwanted ontogenetic pathways and outcomes? Do development-enhancing regulatory patterns in childhood differ from those in old age?

This project investigates motivational, cognitive, and affective processes that regulate human development across the lifespan. Its conceptual framework derives from the metamodel of selection, optimization, and compensation (SOC; cf. Baltes & Baltes, 1990). According to the SOC metamodel, successful development requires the regulation of four universal developmental mechanisms: elective selection, loss-based selection, optimization, and compensation (e.g., Baltes & Baltes, 1990, Freund & Baltes, 2000; see Figure 1).

The project is composed into three subprojects. The first, *Goals and Preferences,* focuses on motivational aspects of lifespan development, and attempts to capture the regulatory function of SOC mechanisms in real-life settings. The second, *Lifespan Differences in Selection Dynamics,* seeks to study age differences in selection from a cognitive-experimental perspective that permits time series analyses of regulatory behavior. The third, *Formal Modeling of Developmental Self-Regulation,* aims at specifying interrelations among SOC mechanisms through nonlinear differential equations and related mathematical tools (Riediger, Li, & Lindenberger, in press). Subprojects II and III were started in Fall 2004. Therefore, this report concentrates on the first subproject.

Subproject I: Goals and Preferences

Life-Management Strategies and Adaptive (Successful) Development

We expect that adults of different ages use different combinations of SOC mechanisms as strategies to regulate their lives, and that use of these strategies fosters developmental success in various life domains. A series of age-comparative studies using self-report measures of SOC mechanisms and developmental out-

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A metamodel of adaptive development
The model of selection, optimization, and compensation
(Baltes & Baltes, 1990)

Central proposition
Adaptive development results from the interaction of three universal developmental regulatory processes:

1. Selection (elective and loss-based)
Focusing one's resources on a subset of potentially available options, either in response to new demands or tasks *(elective selection)* or in response to actual or anticipated losses *(loss-based selection)*
→ Directionality aspect of development

2. Optimization
Acquisition, refinement, and coordinated application of resources directed at the achievement of higher functional levels
→ Growth aspects of development

3. Compensation
Efforts to maintain a given level of functioning despite actual or anticipated decline in or loss of previously available resources
→ Regulation of loss in development

Figure 1. The model of selection, optimization, and compensation (Baltes & Baltes, 1990): Central position and definitions of the three processes.

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comes generally confirmed this expectation. Across all age groups, higher engagement in SOC-relevant life-management strategies was associated with indicators of concurrent as well as future developmental success, such as facets of positive psychological functioning, emotional well-being, and life satisfaction. At the same time, age-related differences in the extent of self-reported engagement in SOC were observed. Middle-aged adults reported stronger engagement than younger and older adults in loss-based selection, optimization, and compensation. Elective selection showed a linear increase from early to middle and late adulthood (see Figure 2). A likely interpretation of these results is that younger adults seek to explore different developmental pathways to find their way in life, and also have the prerequisite internal resources to do so. As individuals move into middle adulthood, they acquire and refine resource-efficient life-management strategies. Most middle-aged adults know their goals in life and selectively pursue these choices. Engagement in SOC strategies (i.e., goal selection and pursuit), however, is itself effortful and resource intensive. Therefore, age-associated decline in internal resources (e.g., sensorimotor and cognitive abilities) limits the expression of optimizing goal pursuit and counteracting goal-related losses (i.e., loss-based selection, compensation).

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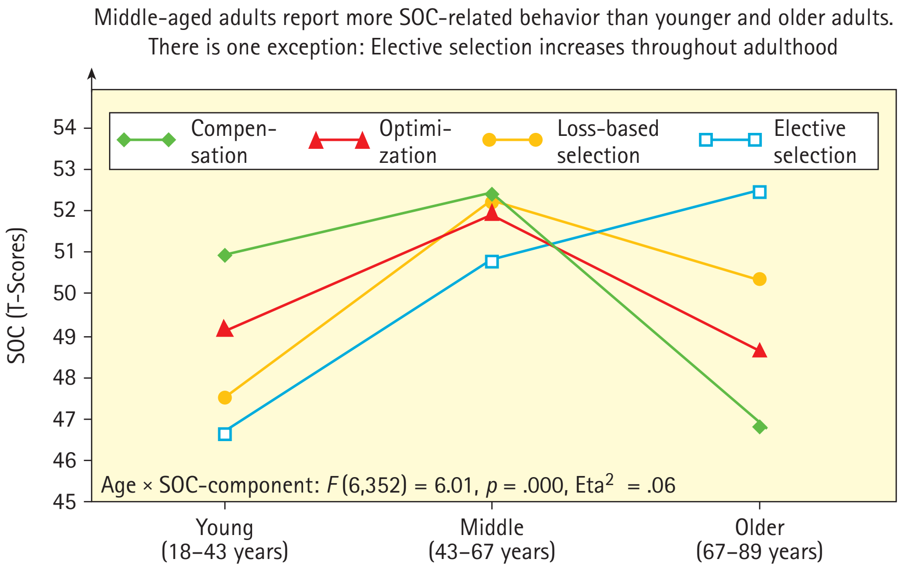
Figure 2. Adult age-group differences in self-reported engagement in SOC-relevant behaviors: Middle-aged adults report more SOC-related behaviors than younger and older adults. There is one exception: Elective selection increases throughout adulthood (N = 181; adapted from Freund & Baltes, 2002).



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Elective selection may become more pronounced with age for the same reason, reflecting the necessity to focus the remaining resources efficiently on a few important goals (Freund & Baltes, 2002).

Adaptive Goal Selection and Goal Pursuit

Developmental goal orientation. Selection and goal pursuit were also examined at the level of manifest goal-directed action to obtain a more direct picture of action goals and motives that enhance the likelihood of positive (e.g., desired) developmental outcomes during different phases of life. We examined whether basic motivational orientations show differential developmental trends in intensity and adaptive value during adulthood that can be conceptualized as adaptations to decreasing internal resources. Three basic motivational orientations were set apart (cf. Dissertation Natalie Ebner; Freund & Ebner, in press): (a) attaining higher levels of functioning; (b) maintaining achieved levels of functioning; and (c) preventing from losses in functioning. One series of experiments investigated the effect of framing tasks in terms of optimization (i.e., improving performance) or compensation (i.e., maintaining previous performance in more difficult task conditions) on younger and older adults' persistence (Freund, 2005). Younger adults were more motivated and persistent when trying to achieve higher levels of performance than when trying to counteract a loss. Conversely, older adults showed higher persistence when engaged in compensation than when aiming at maximum performance. Using both self-report and experimental assessments, the same basic pattern was found for adults' motivational orientation regarding self-chosen personal goals (see Figure 3; Dissertation Natalie Ebner). At the same time, these studies again suggested adult age differences in the adaptive value of various motivational preferences. Loss avoidance was associated with impaired psychological well-being in younger, but not in older adults. Orienting goals toward maintaining functioning was positively associated with psychological well-being in older, but not in younger adults. Thus, resource limitations in action regulation seem to increase in salience and importance with advancing adult age. Shifts in motivational orientation from promoting gains toward maintaining functioning and preventing losses may allow individuals to successfully adapt to changing ratios of resource gains over resource losses.

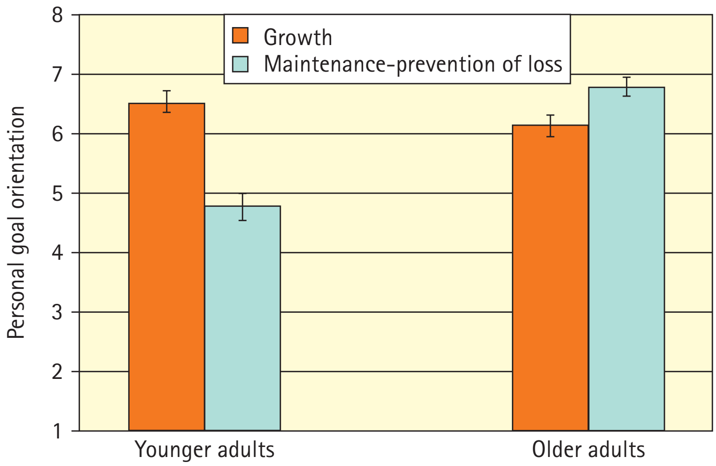

Figure 3. Adult age-group differences in motivational orientation of self-reported personal goals: Goals of younger adults are primarily oriented toward growth, whereas goals of older adults are primarily oriented toward maintenance-prevention of loss (*N* = 100; Study 2 in dissertation Ebner).

Developmental goal structures. People typically pursue several developmental goals at once that are more or less related to each other (Riediger, in press). Specifically, these goals may influence each other in positive (facilitative) and negative (interfering) ways. We propose that intergoal facilitation occurs when the pursuit of one goal simultaneously increases the likelihood of success in reaching another goal. Such facilitation may result from instrumental relations among goals and from overlapping goal-attainment strategies. In contrast, intergoal interference occurs when the pursuit of one goal impairs the likelihood of success in reaching another goal. Intergoal interference may result from resource limitations and from incompatible goal-attainment strategies. In a series of experimental field studies, we found that facilitation and interference among personal goals are indeed associated with indicators of successful development: Intergoal interference is associated with impairments in subjective well-being, and intergoal facilitation is associated with enhanced behavioral involvement in goal pursuit. These associations hold both among younger and older adults (Riediger & Freund, 2004).

From a lifespan perspective, investigating individuals' engagement in goal pursuit is particularly gratifying because many goals remain just that: goals. Wanting to lead a healthy life and exercising regularly are examples of goals many people hold, but do not actually pursue. Active life management, that is, shaping one's life in aspired directions, however, requires goal-directed action. In a multi-method field experiment, we found that older adults pursue their self-selected goals more intensively than younger adults (see Figure 4; Riediger, Freund, & Baltes, 2005). Furthermore, people's self-reported activities as sampled in a diary study showed that more intensive goal pursuit among older adults could not be attributed to age dif-

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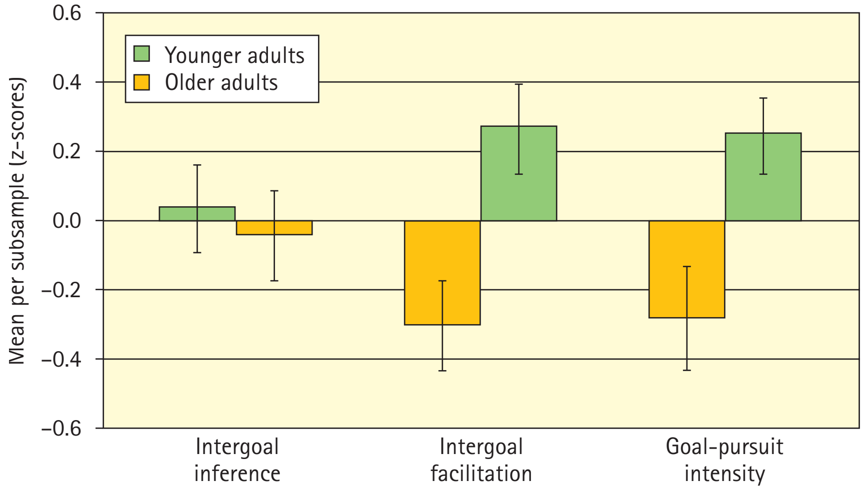

Figure 4. Intergoal interference, intergoal facilitation, and intensity of goal pursuit in younger and older adults: Older adults report more mutual facilitation among their goals, and pursue their goals more intensely than younger adults. This higher goal-pursuit intensity is in part a consequence of more mutually facilitative goals in older adulthood. Younger and older adults do not differ in the extent of interference among goals (*N* = 111; Study 1 in Riediger, Freund, & Baltes, 2005).

ferences in available time. Instead, higher goal-pursuit intensity of older adults is, at least in part, a consequence of positive adult age differences in mutual goal facilitation (Riediger et al., 2005). Furthermore, higher intergoal facilitation in later adulthood is also associated with greater goal-related selectivity. Older adults, for example, tend to narrow in on goals in life domains they regard as central to their life satisfaction. Younger adults, in contrast, more often report goals referring to life domains that they regard as unimportant for their life satisfaction. Overall, our findings form part of a recently evolving line of research suggesting that motivational and volitional processes show positive developmental trends from early to later adulthood.

Beyond the Individual: An Interpersonal Perspective on Goal Processes

The fabric formed by developmental goals covers more than the individual. Rather, people co-construct their development as couples, families, or in other groups. We have begun to investigate the role of goals for dyadic development in young adult couples. Results from a first study indicate that the extent to which partners mutually know their personal goals is positively associated with partnership quality, and that mutual goal knowledge becomes more important with increasing partnership duration. Another facet of goal processes in couples is reflected in the extent to which both partners agree in their ideas about dyadic goals, which we define as mental representations of the couple's common future. Initial results show that dyadic goal setting is an important characteristic in people's subjective theories of high-quality partnerships. However, young adults do not necessarily know how well their ideas on dyadic goals correspond with those of their partners, and the actual (externally rated) dyadic-goal correspondence appears to be quite independent of subjective evaluations of partnership quality. A one-year follow-up is currently underway to identify prospective associations between dyadic-goal processes and partnership development.

Subproject II: Lifespan Differences in Selection Dynamics

According to the SOC theory, selection is particularly important when processing resources are scarce. Everyday cognitive functioning is a continuous stream of simultaneous and sequential multi-tasking (e.g., finding one's way through a mall while memorizing a shopping list, watching one's purse, and talking to a friend), thus requiring flexible resource allocation across functions and task domains on the part of the individual. In this new subproject, we will use a multi-tasking paradigm to investigate lifespan age differences in selection dynamics, with the aim to advance a developmental process model of the selection mechanism in SOC theory.

Ontogenetic changes in selection margins. Given the more positive, the more balanced, and the more negative gain-loss ratio of developmental resources in childhood, adulthood, and old age, respectively, we expect lifespan age differences in mechanisms of selection. In particular, we propose the concept of *selection margins* to study the development of adaptive resource allocation processes in multiple-task situations (see Figure 5).

The *width* of selection margins refers to the extent of the deviation between self-selected and maximally manageable number of simultaneous tasks. We assume that selection width is influenced by the accuracy of people's estimates of the number of tasks they can maximally manage, which in turn should be a function of performance variability and the accuracy of performance and error monitoring. We expect that older adults and children will show wider selection margins in cognitive tasks than young adults.

The *direction* of selection margins is characterized by whether the individual chooses task numbers in excess or below his or her current ability level. If individuals select to work with a number of subtasks that is smaller than their maximum manageable difficulty, their selection margin is said to be *conservative*. Conversely, if individuals select to work with a number of subtasks in excess of their maximum manageable difficulty, their selection margin is termed *progressive* (see Figure 5). We assume that the direction of selection margins is influenced by people's expectations of the future development of their performance. Progressive selection margins should result from expected improvement, and conservative selection margins from expected decline. We further assume that such expectations are a function of past experiences of improvement or decline in abilities, of age-normative expectations, and concurrent task performance. Older adults may therefore more likely use conservative selection margins, whereas children may use more progressive selection margins.

Finally, we assume that the *function* or adaptivity of selection margins depends on the actual gradient of performance development, which is a function of biological capacity and contextual opportunities and constraints. Progressive selection margins should be adaptive in childhood,

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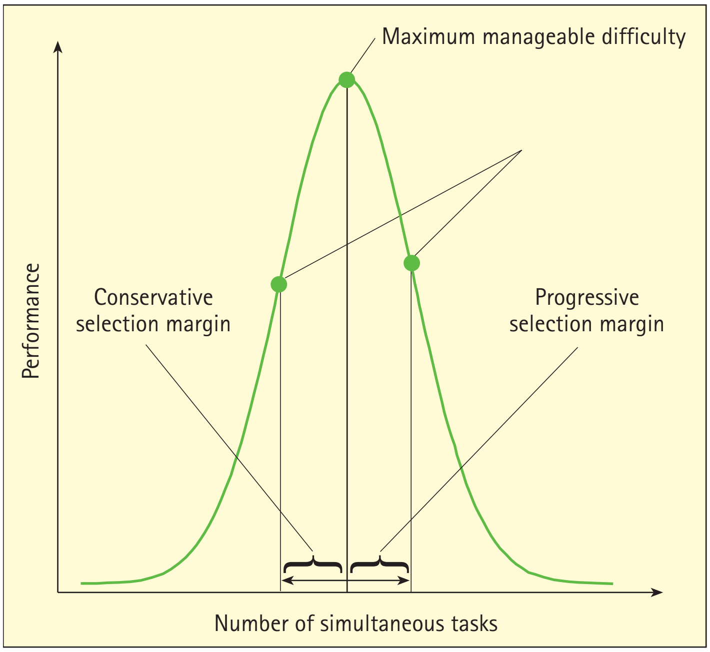

Figure 5. Schematic diagram of selective margins defined as discrepancies between the number of multiple tasks an individual could maximally manage given the available processing resources and the number of tasks he or she actually selects to work on.

when cognitive abilities are on a growth trajectory and when working on a number of tasks that exceeds the child's current ability level should stimulate the full utilization of the developmental potential and thus accelerate the improvement of functioning. Progressive selection margins of moderate width might be most adaptive in this regard. In old age, however, conservative selection margins should be adaptive because they prevent old adults from overtaxing their capacity, which—in contrast to childhood—would not result in rapid improvement of ability levels because cognitive mechanics are on a trajectory of accelerated decline. In this sense, conservative selection margins in older adulthood should function as a mechanism of anticipatory loss-based selection. Conservative selection margins of small width might be most adaptive in this regard, that is, selection margins that are small enough to keep the individual safely away from their limits without severely constraining the expression of the available capacity. These predictions are currently tested in an experimental paradigm in which participants are continuously asked to select the number of tasks they wish to work on next.

Subproject III: Formal Modeling of Developmental Self-Regulation

As a general set of tools for adaptive resource allocation, SOC mechanisms are intrinsically dynamic. We wish to implement SOC mechanisms in formal models that specify the dynamics of adaptive resource allocation, in general, and of experiential influences on selection, in particular. In collaboration with visiting scientists (e.g., Sy-Miin Chow from University of Notre Dame), special attention will be given to nonlinear dynamical systems models, agent-based models, and recursive attractor models. The long-term goal of this subproject is to transform the SOC metamodel into a formal theory of lifespan development.

Modeling of age differences in resource competition and task prioritization through nonlinear differential equations. Dynamic systems models characterize changes according to specified functional relations and parameters that determine their current states in terms of previous states. One subclass of dynamical models, the predator-prey model, has recently been applied to study adult age differences in dual-task performance. Extending the predator-prey model to characterize dual-task performance, adult age differences in intra- and inter-task resource competition can be specified as mutually related differential equations, thereby permitting the formal description and prediction of task selection behavior and performance levels as a function of resource competition. We will use the predator-prey model to formally describe age differences in task prioritization under conditions of walking while memorizing. Given that tripping over and falling has salient negative functional significance in old age, we predict that older adults allot relatively more processing resources to walking, compared to younger adults, particularly when walking is made difficult (e.g., stepping over obstacles).

Modeling lifespan age differences in experiential selection through neural networks. Another class of dynamic process models that has been commonly applied to study child developmental and aging changes is neural networks. Neural networks are able to capture dynamic aspects of behavior because their internal representations depend jointly on network parameters, input-output mappings, and learning history. Therefore, neural networks provide a suitable framework for studying age differences in experiential selection. Throughout life, experiences help to shape individuals' habits and preferences. These experiences, in turn, affect goal and task selection, thereby enhancing the likelihood of certain future experiences, and decreasing the likelihood of others. In some cases, experiential selection helps the deliberation of selecting a particular goal or action; in other cases, habits introduce conflict between current task requirement and old behavior and thus hamper current action (see Figure 6). We plan to use neural network models to examine how lifespan age differences in selection mechanisms influence behavior when current task requirements conflict with well-established habitual responses.

Principal Investigators

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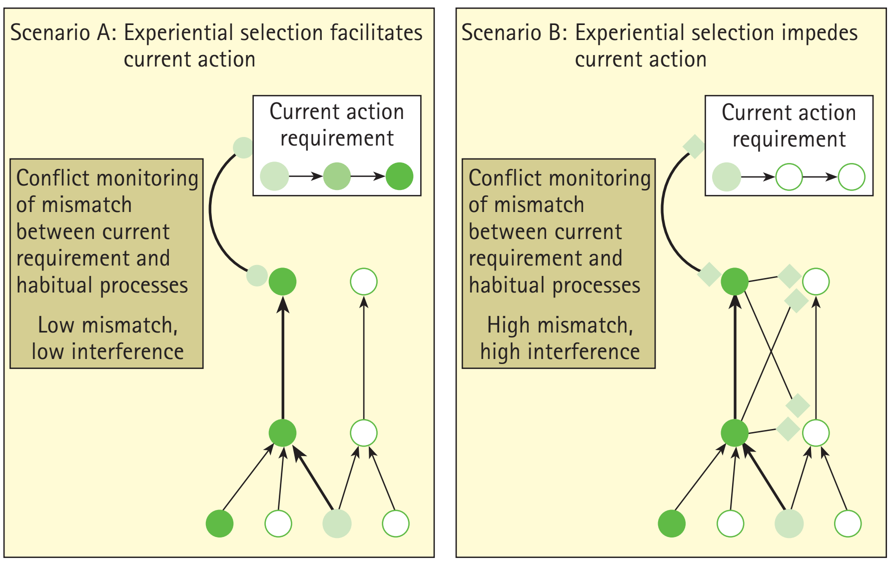

Figure 6. Schematic diagram of two scenarios of possible interactions between experiential selection and current actions: Habituated (experientially selected) processes are linked with thick dark lines. When the conflict between current action requirement and experientially selected processes is low, experiential selection facilitates current action (Scenario A). In contrast, when conflict between current action requirement and experientially selected processes is high, experiential selection hampers current action (Scenario B).

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Research Project 5
Interactive Brains, Social Minds

This new project plans to investigate the development of behavioral and neuronal mechanisms that permit individuals to coordinate their ongoing behavior in time and space. The empirical focus is on temporal aspects of interpersonal action coordination as assessed by simultaneous EEG, EMG, and behavioral recordings. Activities requiring such coordination include performing music, singing, dancing, and collective sports. More importantly, general properties of social behaviors, such as joint gaze, imitation, and turn-taking probably also fall under this category. Therefore, the ability to align one's action in time with the action of another person may play a critical role in social development. Interpersonally coordinated behavior may reflect basic dispositions and needs, and pleasure associated with such behavior may reinforce activities serving important evolutionary functions, such as early mother-child interaction and reproduction.

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So far, the dominant research strategy in social cognitive neuroscience has focused on understanding how individualized brains process socially embedded information. Questions about the online dynamics between multiple brains—capturing multiple interactive brains during interpersonal interaction—have yet to be pursued. A central empirical objective of this project is to identify neuronal mechanisms that allow individuals to coordinate and adjust their individual contributions to a coordinated action with high temporal precision. We conjecture that neural networks supporting social cognition, in general, and theory of mind abilities, in particular, also support interbrain couplings during interpersonally coordinated voluntary action. Preliminary results from pilot studies suggest that this hypothesis can be meaningfully addressed with frequency analyses of standard electrophysiological recordings (EEG and EMG).
Specifically, we conjecture that brain mechanisms permitting interpersonally coordinated behavior have to meet two constraints: (a) They need to be sufficiently fast to permit the degree of interpersonal coordination actually observed; (b) they need to integrate and regulate sensory, motor, and brain activity to generate and sustain action coordination between two or more persons. Coher-

Figure 1. One of the three new EEG cabins of the LIP research unit. The cabin is sufficiently large to allow for simultaneous EEG recording of up to four individuals.

ent oscillatory activity appears to meet both constraints. First, coherent oscillations bind spatially distributed but functionally related information at the level of individual neurons, cell assemblies, and cortical areas. Onset times and frequency ranges of coherent oscillations are sufficiently fast to permit, in principle, the kind of between-person action coordination observed in humans. Second, coherent oscillations support both perception and motor performance. We have begun to investigate the functional significance of coherent oscillations with a variety of paradigms ranging from highly controlled activities, such as coordinated tapping, to less controlled but behaviorally rich and emotionally salient actions, such as performing music or kissing.

The Center for Lifespan Psychology 2004

Left to right: Viktor Müller, Martin Lövdén, Michael Schellenbach, Jacqui Smith, Florian Schmiedek, Daniel Grühn, Oliver Huxhold, Susanne Scheibe, Julia Delius, Agneta Herlitz, Dennis Gerstorf, Albina Bondar, Natalie Ebner, Yvonne Brehmer, Sabine Schäfer, Christina Röcke, Yee Lee Shing, Anna Kleinspehn, Dana Kotter, Markus Werkle-Bergner, Shu-Chen Li, Ute Kunzmann, Lars Bäckman, Paul B. Baltes, Ulman Lindenberger.

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Research Project 6
Wisdom: The Integration of Mind and Virtue

The search for human strengths has a long history in philosophical writings. Since antiquity, one guide in this search has been the concept of wisdom. At the core of this concept is the notion of a perfect, perhaps utopian, integration of knowledge and character, mind and virtue (e.g., Baltes, 2004; Baltes & Staudinger, 2000; Kunzmann & Baltes, in press). A focus on human strengths and excellence is also a key feature of the recent advent of the movement of positive psychology.

The territory of wisdom can be approached in several ways, for instance, by a person focus (what are the characteristics of "sages"?) or by a conceptual orientation (what is wisdom as an abstract system?). In our work, we prioritized the second approach in order to obtain a golden standard on the utopia of wisdom as a body of outstanding knowledge about the human condition and the conduct of life. In subsequent research, we considered the first line of inquiry, and asked questions about the characteristics and developmental conditions of persons who, relatively speaking, achieve higher or lower standings in the theoretically specified wisdom domain (Baltes & Kunzmann, 2004).

Specifically, and consistent with Western philosophical conceptions, our project has defined wisdom as an expert knowledge system about fundamental problems related to the meaning and conduct of life. These problems are typically complex, ill-defined, and have multiple, yet unknown, solutions. For instance, deciding on a particular career path, accepting the death of loved ones, dealing with human mortality, or solving long-lasting conflicts among family members, are illustrations of the type of problem that calls for wisdom-related expertise.

Solutions or thinking about possible solutions to these problems can be quantified based on five criteria derived from our theory-based wisdom conception (Baltes & Smith, 1990; Baltes & Staudinger, 2000). Expert knowledge about fundamental problems referring to the meaning and conduct of life is thought to approach wisdom if it meets all five criteria. Two criteria are labeled basic because they are characteristic of all types of expertise or expert knowledge systems; these are:
(a) rich factual knowledge about human nature and the life course and (b) rich procedural knowledge about ways of dealing with life problems.
The three other criteria are labeled metacriteria because they are thought to be unique to wisdom:
(c) lifespan contextualism, that is, an awareness and understanding of the many contexts of life, how they relate to each other and change over the lifespan; (d) value relativism and tolerance, that is, an acknowledgment of individual, social, and cultural differences in values and life priorities; and (e) knowledge about handling uncertainty, including the limits of one's own knowledge and the knowledge of the world at large.

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Task: A 15-year-old girl wants to get married right away. What could one/she consider and do?

Low wisdom score
A 15-year-old girl wants to get married? No, no way, marrying at age 15 would be utterly wrong. One has to tell the girl that marriage is not possible. (After further probing) It would be irresponsible to support such an idea. No, this is just a crazy idea.

High wisdom score
Well, on the surface, this seems like an easy problem. On average, marriage for 15-year-old girls is not a good thing. I guess many girls might think about it, however, when they fall in love for the first time. And, then, there are situations where the average case does not fit. Perhaps in this instance, special life circumstances are involved, such that the girl has a terminal illness. Or the girl has just lost her parents. And also, this girl may not be from this country. Perhaps she lives in another culture and historical period.

Figure 1. Illustration of two extreme responses to wisdom tasks.

To assess wisdom, we present our study participants with short vignettes describing difficult life problems of fictitious people, and ask them to think aloud about these problems. For example, a problem concerning life management reads: "A 15-year-old girl wants to move out right away. What could one/she consider and do?" Trained raters evaluate our participants' responses for wisdom-related knowledge as determined by the five criteria described above. Figure 1 depicts two excerpts of extreme responses to one of our wisdom tasks.

Given that wisdom has been considered an ideal endpoint of human development, a longstanding goal of our research has been to describe and explain age-related differences in wisdom-related knowledge (e.g., Baltes & Kunzmann, in press; Baltes & Smith, 1990; Pasupathi, Staudinger, & Baltes, 2001; Smith & Baltes, 1990; Staudinger, Smith, & Baltes, 1992). A second goal of our work has been to study the factors that promote the activation of wisdom-related knowledge in a given situation (Staudinger & Baltes, 1996; Böhmig-Krumhaar, Staudinger, & Baltes, 2002). Finally, during the last couple of years, we have become increasingly interested in understanding the motivational-emotional nexus of wisdom-related knowledge. Thus, we have studied the motivational, social, and emotional characteristics of persons varying in level of wisdom-related knowledge (e.g., Baltes & Kunzmann, 2004; Kunzmann, 2004; Kunzmann & Baltes, 2003a; Stange, 2004).

Evidence for Age-Related Differences in Wisdom-Related Knowledge

As seen in Figure 2, our studies suggest that wisdom-related knowledge increases during adolescence and young adulthood (Pasupathi et al., 2001) and then remains stable, at least up to age 75 (see also Staudinger, 1999). At first sight, the stability of wisdom across most of adulthood is at odds with the idea that wisdom is a positive aspect of aging. However, given that basic

Figure 2. Cross-sectional age gradients and scatter plots for wisdom-related performance. The left panel shows data from Pasupathi, Staudinger, and Baltes (2001) including outcomes of a spline analysis. The right panel summarizes results from several studies with adult samoles (see also Baltes & Staudinger, 2000).

cognitive functions lose efficiency relatively early in the lifespan, for most people, the maintenance of wisdom-related knowledge might be the best possible outcome that adulthood and old age can bring about. That many adults do not experience an increase in wisdom-related knowledge during the adult years is also consistent with our theoretical model of the ontogenesis of wisdom. In this model, wisdom-related knowledge is not strictly tied to the aging process; rather, we have argued that the acquisition and optimization of wisdom-related knowledge requires a wide range of supportive conditions and processes related to an individual's personality, cognitive capacities, environment, and life history (e.g., Baltes & Smith, 1990; Baltes & Staudinger, 2000). Correlational evidence from adult samples supports this idea. For example, those who are open to new experiences, who have a certain level of academic intelligence, or who think about the how and why of an event rather than simply whether it is good or bad display higher levels of wisdom-related knowledge (e.g., Staudinger, Lopez, & Baltes, 1997; Staudinger, Maciel, Smith, & Baltes, 1998). There is also evidence that adults who specialize in professions, which provide extensive training and practice in difficult and uncertain life matters (e.g., clinical psychology), show higher wisdom-related performance than professionals from fields in which training and job tasks were not specifically dedicated to dealing with fundamental life problems (Staudinger et al., 1992). Together, this evidence suggests that age itself does not bring higher levels of wisdom-related knowledge, and yet a number of age-associated factors appear to be highly relevant to the further development of wisdom during the adult lifespan.

The Activation of Wisdom-Related Knowledge in the Laboratory

In experimental work, we have shown that the expression of wisdom-related performance can be enhanced by social and cognitive interventions. For example, Boehmig-Krumhaar et al. (2002) demonstrated that a memory strategy, namely, a version of the method of loci, in which participants were instructed to travel on a cloud around the world, can be used to focus people's attention on cultural relativism and tolerance. As predicted, following this intervention, participants expressed higher levels of wisdom-related knowledge, especially value relativism and tolerance. To explore the social-mind component of wisdom, Staudinger and Baltes (1996) conducted an experiment in which study participants were asked to think aloud about a wisdom problem under several experimental conditions involving imagined and actual social interactions. Specifically, before responding individually, some participants had the opportunity to discuss the problem with a person they brought into the laboratory and with whom they usually discuss difficult life problems; others were asked to engage in an inner dialogue about the problem with a person of their choice, or to think about the problem on their own. The results supposed the notion of a strong interactive minds component. Actual social dialogue and the inner-voice dialogue increased performance levels by almost one standard deviation. One important implication of these studies is that many adults may have the capacity to perform better on wisdom tasks than they actually often do. To do so, they need to engage their social context as a facilitator.

The Emotional, Motivational, and Social Dynamics of Wisdom-Related Knowledge

A third focus of our work has been the investigation of emotional, motivational, and social dynamics linked to wisdom-related knowledge. Related to this research focus is our work on the consequences of wisdom-related knowledge for a person's lifestyle and behavior in a given situation (e.g., Baltes & Freund, 2003; Baltes et al., 2002; Kunzmann, 2004; Kunzmann & Baltes, 2003a; Kunzmann, Stange, & Jordan, in press). As Kunzmann and Baltes (2003b) reported, for example, adults with above-average levels of wisdom-related knowledge evince a complex and more modulated profile of affective feelings, they show a preference for values that consider the welfare of others, and report engaging themselves in the interest of others. Moreover, adults with above-average levels of wisdom-related knowledge reported that they prefer cooperative strategies of conflict management over one-sided strategies that focus on one's own interest (dominance), the opponent's interest (submission), or no interest at all (avoidance; see also Figure 3).
We also have conducted laboratory studies to investigate under more standardized conditions the difference that wisdom-related knowledge

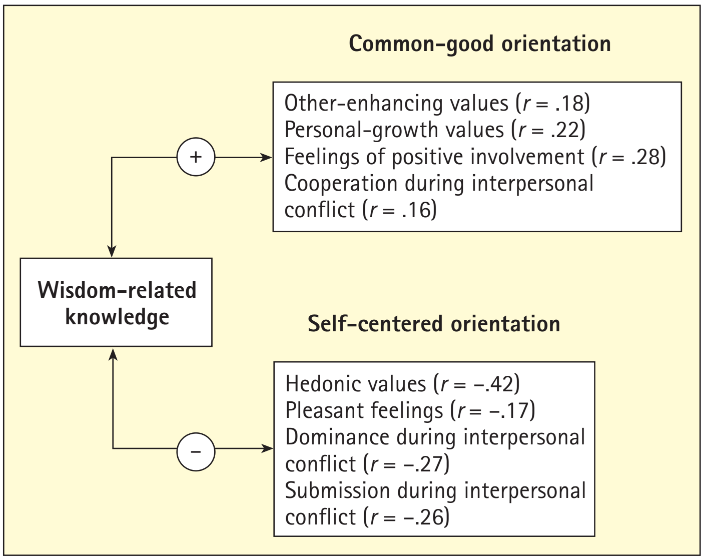

Figure 3. Wisdom-related knowledge and its association with motivational, affective, and social-behavoral dispositions. The evidence suggests that wisdom is incompatible with a self-centered life.

makes for adults' social and emotional behaviors. In one such experiment we presented short film clips about fundamental losses (e.g., death of loved ones, life-threatening diseases) known to elicit strong feelings of sadness (Kunzmann & Grühn, in press). The evidence from this study suggests that people with above-average levels of wisdom-related knowledge react quite differently to such problems than do people with low levels of wisdom-related knowledge. Possibly due to their better understanding of the significance of fundamental losses, persons with higher wisdom-related knowledge spontaneously reacted with greater sadness both on the level of subjective feelings and outer expressions (Kunzmann & Baltes, in press). In another study, we found that adults with above-average levels of wisdom-related knowledge were more likely to express empathic concern with others in need, and they were more accurate in judging other people's inner feelings than people with low levels of wisdom-related knowledge (Kunzmann & Richter, 2004).

Who Is Considered a Wise Person?
Related to this work is an experimental person perception study conducted as a dissertation by Antje Stange. She investigated the degree to which people's social behaviors, verbalized wisdom-related knowledge, and chronological age make them appear to be wise and sought out as an advisor (Stange, 2004). More specifically, participants in her study had to evaluate an advisor's level of wisdom after they observed advisors (varying in age, empathic listening, and substantive quality of wisdom knowledge) interacting with a young person who talked about a serious problem. The findings suggest that participants' evaluations did not only depend on the advisor's level of wisdom-related knowledge as expressed in his or her verbal advice, but also on the advisor's age and nonverbal listening behavior. In fact, advisors who met all three wisdom criteria (high wisdom-related knowledge, empathic listening behavior, and older age) were most likely to be considered as wise. This evidence supports the idea that wisdom as an attributed person characteristic is a multidimensional concept requiring the simultaneous consideration of experience-based, behavioral, and cognitive qualities. While processing the cues of age and listening behavior was fast, the information about wisdom knowledge took longer to process.
Together, our evidence has been systematically extended from wisdom as a theory of knowledge to wisdom as a characteristic of people and behavioral expressions. The results are consistent with our expectations. Together, the findings help us move toward a more comprehensive conceptualization of wisdom that highlights its special strength, namely, the integration of mind and virtue as the optimum of human functioning and as a guidepost for desirable (successful) developmental outcomes involving the self as well as the role of oneself in the positive development of others (Baltes, 2004; Baltes et al., 2002; Baltes & Freund, 2003; Baltes & Kunzmann, 2004; Baltes & Staudinger, 2000; Kunzmann & Baltes, in press).

Research Project 7
Toward a Psychological and Developmental Theory of Lifespan-Longing (Sehnsucht)

One of the exciting events in lifespan psychology is the identification of novel constructs that appear worthwhile of investigation when considering the life course as a whole (Baltes, Lindenberger, & Staudinger, in press). A first construct attracting such attention was wisdom (Baltes & Smith, 1990; Baltes & Staudinger, 2000; Kunzmann & Baltes, in press; see Project 6). Recently, we have added the concept of "Sehnsucht." We assume that "Sehnsucht" is a holistic, domain- and lifespan-integrative concept that may further our understanding of human development in its complexity and richness. It is also a construct that fits a central piece of lifespan theory, namely that a key feature of life in the modern world is a permanent sense of incompleteness, objectively and subjectively (Baltes, 1997). "Sehnsucht" is difficult to translate into English. After much deliberation, we have chosen to characterize the emerging research program as the "Psychology of Lifespan-Longing." We view lifespan longings as emotional and mental representations of personal peaks of life, akin to personal utopias. In principle, however, these personal utopias are unattainable and, therefore, ambivalent in emotional quality.

In German everyday life, the concept of "Sehnsucht" is salient. In fact, "Sehnsucht" was the third most often nominated word in a recent contest of "The most beautiful German word" (*Spiegel Online*, 2004). Such popularity illustrates the importance that German culture allocates to emotional and mental representations of unfulfilled wishes of life, and probably also to individual and collective reflections about the "non-realizability of dreams" and "chronic incompleteness" as part of life. Aside from attending to the core of everyday, dictionary-like definitions of "Sehnsucht," we are applying principles of lifespan psychology (e.g., Baltes, 1987, 1997) to frame our approach on a conceptual level. Our conceptual analysis suggests a family of six characteristics to capture the structure of lifespan-longing (see Figure 1, for an example).

(1) Lifespan-longing involves feelings of incompleteness and imperfection of life. It reflects the notion that development is a lifelong process that never reaches completion. **(2)** We assume that lifespan-longing comprises representations that are rich in symbolism. **(3)** Consistent with the notion that individuals hold subjective beliefs about their own optimal development, we assume that lifespan-longing involves personal utopias of ideal life realities and optimal life courses. **(4)** Lifespan-longing reflects the conception that development always involves both gains and losses: It has an ambivalent, bittersweet emotional quality. **(5)** Lifespan-longing focuses on the life course as a whole, that is, on the personal past, present, and future. It is an "ontogenetic tritime phenomenon."
(6) Lifespan-longing elicits reflec-

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Prototype example of a lifespan-longing: A house by the sea

I always wanted to have a house and live by the sea. It is the missing piece in my life *(personal utopia, incompleteness).* I enjoy imagining myself walking along the seashore and hearing the sounds of the waves and seagulls. Yet, I know that real life will never be that perfect, and this makes me sad *(nonrealizability of personal utopia, ambivalent emotions).*

The sea has been part of my childhood, and it symbolizes something missing in my life today *(tritime focus).* It has to do with freedom, endless time, and being close to nature *(symbolic nature).* I wonder: how do I want to live *(reflection)*? In a way, I would hope that when I am old, I would be able to buy a house by the sea to fulfill my lifespan-longing *(continuing presence of personal utopia, tritime focus).*

Figure 1. This figure presents a theory-based prototype example of a lifespan-longing. The example has been constructed to illustrate the six structural characteristics that our theoretical analysis assigns to the mental representations of lifespan-longing (Sehnsucht).

tions and evaluations of life and one's standing relative to ideals, or to others who serve as guideposts for optimal development.

The major study conducted so far was dissertation work by Susanne Scheibe, which was cosupervised by Paul B. Baltes and Alexandra M. Freund (Scheibe, 2005; Scheibe, Freund, & Baltes, submitted). Based on the theoretical frame outlined above, in this study, we developed a self-report questionnaire to assess lifespan-longing. We used this new scale to explore age-related changes in, and possible functions of, lifespan-longing for development. In addition, a master's thesis was completed by Sabine Mayser under the supervision of Michaela Riediger and Susanne Scheibe. This study explored similarities and differences between lifespan-longing and goals in an attempt to show that lifespan-longing carries uniqueness, especially in relation to the psychology of goals.

Self-Report Measure of Lifespan-Longing

The outcome of the scale development was rather encouraging. We asked 299 study participants (aged 19 to 81 years) to report on their three most important lifespan-longings. The questionnaire inquired about the six structural characteristics and other important aspects of lifespan-longings. As shown in Figure 2, the measurement structure corresponded to our theory-guided expectations. A two-factor solution with the two factors of intensity/scope and nonrealizability/ambivalence resulted. There was evidence for temporal stability (over 5 weeks), with values between .59 and .85. These data show that reliability is satisfactory, and that lifespan-longing exhibits a tendency toward the dispositional kind. Surprisingly, there were no clear age and gender differences. Thus, adults of different ages and genders reported their lifespan-longings to be equally intense, broad, unrealizable, and ambivalent.

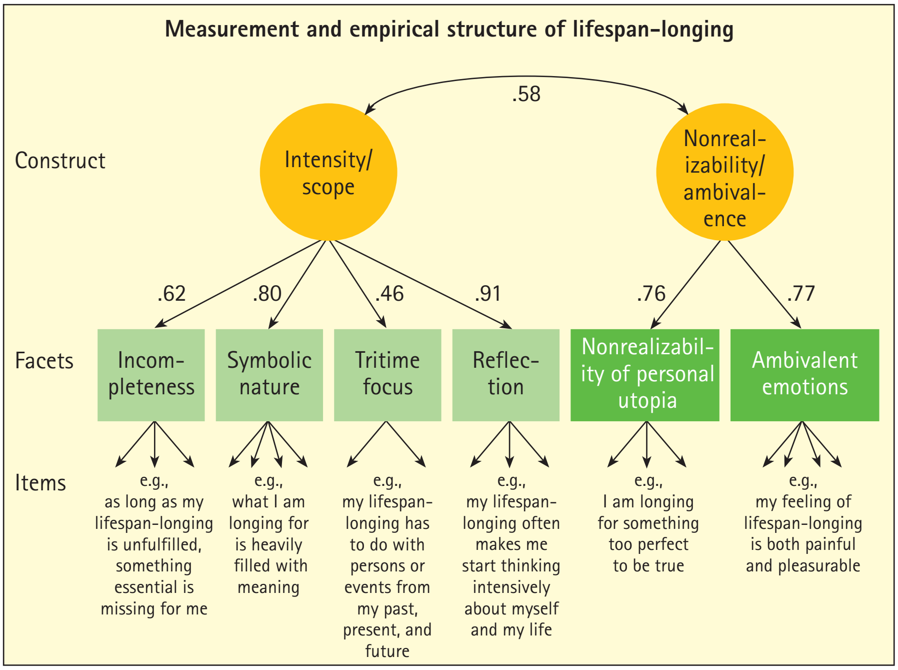

Figure 2. On a general level of analysis, results from a study with 299 adults (aged 19 to 81) showed that lifespan-longing can be described in terms of two structural "factor-analytic" dimensions. Intensity/Scope represents the intensity of incompleteness of life, the amount of associated reflections, and the extension of lifespan-longing across multiple life domains and time periods. Nonrealizability/Ambivalence represents the utopian nature of lifespan-longing representations and the unique bittersweet affect accompanying lifespan-longing. For each facet of lifespan-longing, the figure contains sample items that are part of the questionnaire used in this study.

An interesting by-product was the finding that under conditions of more explicit anonymity (separate questionnaire without identification number), 35 % of participants reported additional lifespan-longings not mentioned under the standard instruction. These included less desirable characteristics, such as infidelity and revenge.

The Regulative Function of Lifespan-Longing in Adult Development and Aging

What is the role of lifespan-longing in planning, managing, and experiencing one's life? Does it give direction? Is it an expression of incompleteness? Is it an indicator of positive or negative states and outcomes? Answers to such questions require careful analysis of antecedent-consequent relationships, considerations of different outcome measures, and likely also the recognition that such associations and causal connections may be nonlinear.

In our first effort, we considered two possible outcomes of lifespan-longing. First, we examined whether lifespan-longings are perceived as functional (facilitative) in development. In this vein, adults in our study reported that their lifespan-longings (1) provided a sense of directionality for development (regarding the past, present, and future life) and (2) helped in regulating losses and incompleteness. Second, we investigated the relationship between lifespan-longing and overall well-being (e.g., positive emotions, life satisfaction). The correlational relationship was negative, that is, individuals with high-level expressions of lifespan-longing reported lower well-being. It can be speculated that lifespan-longing is linked with critical self-reflection about the developmental progression toward personal ideals of life. Thus, intense lifespan-longing might be an expression of unfulfilled personal utopias. However, this negative association between high levels of lifespan-longing and subjective well-being was subject to modulation. Specifically, when persons also reported a strong sense of control over the experience of lifespan-longing, the negative relationship was less strong approaching zero.

Lifespan-Longing and Goals

In the second study, we asked persons to report on their three most important lifespan-longings and their three most important goals. We found important differences between these two concepts. For example, goals were reported to be more concrete, controllable (i.e., one knows the steps necessary for their achievement), and more closely linked to everyday behavior than is true for lifespan-longings. In addition, lifespan-longings were rated as more emotionally bittersweet (painful and pleasurable at the same time) than goals.

In the future, we will inquire further into the antecedents, correlates, and consequences of lifespan-longings and explore their short-term intraindividual, temporal, and contextual dynamics (e.g., stages of lifespan-longing, such as beginning, experience, and conclusion).

Integrative Project
History, Theory, and Method in Lifespan Psychology

In order for a developmental approach—especially of the life-span kind—to be empirically powerful, one must have a warehouse full of methods capable of identifying, representing, and explaining complex long-term historical relationships.
Baltes, Reese, and Nesselroade (1977, p. 106)

Since its foundation by Paul Baltes in 1981, the Center for Lifespan Psychology has sought to promote historical reflection, theoretical integration and expansion, and methodological innovation within developmental psychology and in interdisciplinary context (Baltes, Lindenberger, & Staudinger, in press). Over the years, this emphasis on concepts and methods has evolved into a distinct feature of the Center. The Center will continue this line of work, with special attention to formal theory, computational models, statistical methods, and empirical research tools that connect behavioral to neuronal plasticity.

Lifespan Psychology in Dialogue With Other Disciplines: Exploring Biocultural Co-Construction

Human development from childhood into old age results from reciprocal co-constructive interactions between biological factors and experiential/environmental factors (Baltes, Lindenberger, & Staudinger, in press; Li, 2003; Lindenberger et al., in press). Though most scholars in the behavioral neurosciences subscribe to this view, the mechanisms mediating beneficial and deleterious effects of environment and behavior on brain functioning are not yet well understood. Conversely, social scientists often focus on environmental conditions and tend to ignore potential biological influences. To initiate a productive dialogue on biocultural co-construction, and based on contributions resulting from a conference sponsored by the Center for Lifespan Psychology, Paul Baltes, Patti Reuter-Lorenz from the University of Michigan, and Frank Rösler from the University of Marburg asked neuroscientists and behavioral scientists to articulate their divergent perspectives (Baltes, Reuter-Lorenz, & Rösler, in press—see overleaf; see also Li & Baltes, in press; Staudinger & Lindenberger, 2003). In a similar vein, and together with Lars Bäckman (Karolinska Institute, Stockholm, and visting scientist at the Center in 2004–2005), we addressed methodological advances in the study of brain-behavior dynamics from a multivariate lifespan perspective (Lindenberger, Li, & Bäckman, in press).

Computational Modeling

In earlier work (e.g., Li, Lindenberger, & Frensch, 2000), we proposed neural networks as a computational platform for cross-level integration of lifespan differences in cognitive and neuronal processes. This line of inquiry was extended in two direc-

Scientific Investigators

All LIP scientists

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tions. First, together with Moshe Naveh-Benjamin (University of Missouri-Columbia), we investigated the relation of age changes in neuromodulation to associative binding deficits in old age. Our results support the conjecture that neuromodulatory processes play a basic role in binding by affecting the efficiency of distributed conjunctive coding (S.-C. Li, Naveh-Benjamin, & Lindenberger, in press). Second, in collaboration with Timo von Oertzen (Saarland University), we studied the effects of aging-related increase in intrinsic neuronal noise on stochastic resonance, a fundamental property of physical and biological systems in which noise acts as an amplifier of weak signals. We showed that systems with greater more intrinsic neuronal noise and less plasticity continue to exhibit stochastic resonance at single-neuron and network levels. However, the stochastic resonance effect is smaller and, somewhat counterintuitively, requires more external noise for its operation (Li, von Oertzen, & Lindenberger, submitted). It is planned to test these predictions in psychophysical experiments, and to investigate its applied implications.

Exploration of Statistical Methods

In part together with Paolo Ghisletta (University of Geneva), Chris Hertzog (Georgia Institute of Technology, Atlanta, USA), and Timo von Oertzen (Saarland University), researchers working at the Center have used mathematical analysis and Monte Carlo simulations to examine formal properties and statistical power of widely used statistical methods in developmental research. By formal analysis, we showed that the contribution of correlated change to cross-sectional correlations is small under most conditions (Lindenberger, von Oertzen, Ghisletta, & Hertzog, in prep.). We also found that the power to detect variances and covariances of change in standard longitudinal panel designs is surprisingly small (Hertzog, Lindenberger, Ghisletta, & von Oertzen, submitted). Related work has examined differences and commonalities between multi-level and latent-growth-curve modeling (Ghisletta & Lindenberger, 2004; Lindenberger & Ghisletta, 2004) as well as the statistical and conceptual status of reliability in multivariate time series (Li, Huxhold, & Schmiedek, 2004; Lindenberger & von Oertzen, in press).

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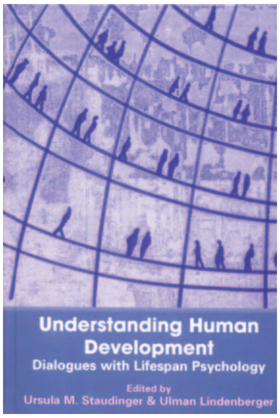

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