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The Center for Lifespan Psychology at the Max Planck Institute for Human Development: Overview of Conceptual Agenda and Illustration of Research Activities

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Abstract

Founded in 1981 by the late Paul B. Baltes, the Center for Lifespan Psychology at the Max Planck Institute for Human Development has helped to establish lifespan psychology as a distinct conceptual approach within developmental psychology. Recently, the Center has extended its research program into developmental behavioral neuroscience. Here, we provide an overview of the Center's conceptual agenda, and present two of its seven research projects in greater detail. Work at the Center is guided by three propositions: (i) to study lifespan changes in behavior as interactions among maturation, learning, and senescence; (ii) to develop theories and methods that integrate empirical evidence across domains of functioning, timescales, as well as behavioral and neuronal levels of analysis; (iii) to identify mechanisms of development by exploring age-graded differences in plasticity. The *Intra-Person Dynamics Project* studies the organization of cognitive abilities within individuals of different ages, and investigates lifespan age differences in the plasticity and components of episodic memory performance. The *Sensorimotor–Cognitive Couplings Project* examines lifespan differences in dynamic dependencies between sensorimotor and cognitive performance. Both projects combine behavioral assessments with methods from developmental neuroscience to delineate age-graded changes in brain–behavior mappings. Current research in other projects includes: (a) behavioral development in very old age, as assessed in the *Berlin Aging Study*; (b) the interplay of motivation, affect, and cognition in developmental regulation; (c) behavioral and electrophysiological mechanisms of social interaction from infancy to adulthood; and (d) formal and statistical issues in structural equation modeling, with an emphasis on latent growth curve modeling. Graduate education and research at the Center profit greatly from cooperation with other institutions in Berlin and Potsdam as well as national and international collaboration. (276 words)

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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.
>
> Johan Nicolaus Tetens, 1777, Vol. I, p. 766 (UL's translation)

Since its foundation in 1981 under the leadership of the late Paul B. Baltes, the Center for Lifespan Psychology at the Max Planck Institute for Human Development has promoted a perspective on behavioral development that seeks to integrate age periods, domains of functioning, timescales, and levels of analysis. In part through these efforts, lifespan psychology has evolved into a distinct conceptual approach within developmental psychology (e.g., Baltes, 1987; Baltes, Lindenberger, & Staudinger, 1998, 2006). More recently, the Center for Lifespan Psychology has extended the conceptual and the empirical scope of its scientific endeavors into the field of developmental behavioral neuroscience (Lindenberger, Li, & Bäckman, 2006; cf. Craik, 2006; Craik & Bialystok, 2006). We begin this article with an outline of the Center's research agenda, which we structure, somewhat arbitrarily, into three interrelated theoretical propositions. Then, two of the seven research projects currently conducted at the Center will be presented in more detail. Table 1 provides an overview of the Center's current research projects and their scientific investigators.

Research at the Center for Lifespan Psychology: Three Guiding Propositions

The following three propositions are meant to highlight essential features of the Center's research agenda. The propositions emphasize conceptual and methodological issues in the study of lifespan behavioral development, and thereby provide a general script for formulating research questions in more specific domains of interest.

Proposition 1: Lifespan Changes in the Individual's Behavior as Interactions Among Maturation, Learning, and Senescence

The general goal of developmental psychology is to identify mechanisms that generate invariance and variability, constancy and change in behavioral repertoires from infancy to old age. By identifying the commonalities, differences, and interrelations in the ontogeny of sensation, motor control, cognition, affect, and motivation, both within and across individuals, developmental psychologists attempt to arrive at more or less comprehensive theories of behavioral development. To provide explanations that qualify as psychological and developmental, the effects of agents external to the developing individual, such as parents' affect attunement, teachers' classroom behavior, or a state's retirement policies, need to be mapped onto mechanisms and organizational laws that operate and evolve within the developing person. Hence, developing individuals, rather than groups of individuals or domains of functioning within individuals, form the privileged system of analysis and explanation (e.g., Molenaar, in press; Nesselroade, 1991).

Individuals organize their exchange with the physical and social environment through behavior (see Figure 1; cf. Lindenberger et al., 2006). On the one hand, the changing brain and the changing physical and cultural environment shape behavioral development. On the other hand, behavior alters both the brain and the environment. Hence, environment and brain act as antecedents, but also as consequents of moment-to-moment variability and long-term changes in patterns of behavior. The components of this system, brain, behavior, and environment, are constantly coupled and cannot be reduced onto each other, as they jointly condition an individual's life trajectory through recursive self-regulation.

In attempts to explain the age-graded evolution of this system, *maturation* and *senescence* denote the operation of age-graded brain mechanisms and their effects on changes in behavior, which are especially pronounced early and late in life. In addition, *learning*, at any point during ontogeny, denotes changes in brain states induced by behavior–environment interactions. Note, however, that maturation cannot take place without learning, and that learning cannot take place without maturation. Similarly, the ways in which senescence takes its toll on the brains of aging individuals depend on individuals' past and present learning and maturational histories. To complicate matters even more, processes commonly associated with maturation are not confined to early ontogeny, and processes related to senescence are not restricted to old and very old age (Raz et al., 2005). For instance, neurogenesis and synaptogenesis, as expressions of maturation, continue to exist in the adult and aging brain (Kempermann, 2005), and declines in dopaminergic neuromodulation, which indicate senescence-related changes in brain chemistry, commence in early adulthood (Bäckman, Nyberg, Lindenberger, Li, & Farde, 2006). Thus, maturation, senescence, and learning mutually enrich and constrain each other throughout the lifespan, and must be understood and studied as interacting forces driving the brain–behavior–environment system. In this endeavor, psychologists occupy a central position because they possess a rich and adequate repertoire of experimental and methodological tools to describe and modify the organization of behavior.

Proposition 2: Lifespan Theory and Methodology Need to Integrate Evidence Across Domains of Functioning, Timescales, and Levels of Analysis

If the lifespan development of behavior is defined to originate from recursive interactions among maturation, learning, and senescence, with the developing individual as the privileged system of analysis, then developmental psychology is faced with three difficult integrative tasks. First, there is the need to integrate theorizing and research practice across functional domains to attain a comprehensive picture of individual development. For instance, sensorimotor and cognitive functioning are more interdependent in early childhood and old age than during middle portions of the lifespan, and developmental changes in either domain are better understood if studied in conjunction (Schaefer, Huxhold, & Lindenberger, 2006). Similar observations can be made for many other domains of functioning whose changes generally have been studied in isolation, such as the ontogeny of social interaction and cognition, or of emotion regulation and motivational states. Empirically, dense multivariate time-series data are needed to assess short-term variability and long-term changes in across-domain dependencies (cf. Molenaar, in press; Nesselroade, 1991; Siegler, 1994).

Second, there is a need to understand the mechanisms that link short-term variations to long-term change (S.-C. Li, Huxhold, & Schmiedek, 2004; Lindenberger & Oertzen, 2006). Short-term variations are often reversible and transient, whereas long-term changes are often cumulative, progressive, and permanent. Establishing links between short-term variations and long-term changes is of eminent heuristic value, as it helps to identify mechanisms that drive development into different directions. For instance, aging cognitive systems show an increase in maladaptive moment-to-moment fluctuations, or decrease in processing robustness, at both behavioral and neuronal levels of analysis. These maladaptive changes may signal impending long-term changes in other characteristics of the system (see Figure 2; S.-C. Li, Lindenberger et al., 2004; Lövdén, Li, Shing, & Lindenberger, 2006). In contrast, other forms of moment-to-moment variability indicate an individual’s ability to bring a wide variety of different strategies to the task, and are positively related to long-term change in both childhood and old age.

Third, to arrive at mechanistic explanations of behavioral change, there is the need to integrate behavioral and neuronal levels of analysis. At any given point in the lifespan, one-to-one mappings between brain states and behavioral states are the exception, rather than the rule, as the brain generally offers more than one implementation of an adaptive behavioral outcome (S.-C. Li. 2003; S.-C. Li & Lindenberger, 2002). Therefore, ontogenetic changes in behavioral repertoires are accompanied by continuous changes in multiple brain–behavior mappings. Some of these re-mapping gradients may be relatively universal and age-graded, whereas others may be more variable, reflecting genetic differences, person-specific learning histories, the path-dependent nature of developmental dynamics, or a combination of the three. The resulting picture underscores the diversity and malleability of the organization of brain and behavior, as well as the constraints on diversity and malleability brought about by (a) universal age-graded mechanisms associated with maturation and senescence, (b) general laws of neuronal and behavioral organization, and (c) cultural-social as well as physical regularities of the environment (Baltes et al., 2006).

In summary, developmental psychology needs theory and methodology apt to integrate (a) multiple domains of functioning, (b) multiple timescales, and (c) multiple levels of analysis. In recent years, the Center for Lifespan Psychology has relied on two methodologies that seem well suited to these conceptual demands. First, random coefficient modeling (RCM), latent growth curve modeling (LGCM), and related statistical techniques have served as versatile tools for the analysis of multivariate data with nested time structures such as trials, blocks of trials, days, weeks, and years. Dynamic extensions of these methods, such as the dual-change score model introduced by McArdle and Hamagami (2001), permit the investigation of directed lead–lag hypotheses with longitudinal panel data (for examples, see Ghisletta & Lindenberger, 2003; Lövdén, Li et al., 2006). Second, neurocomputational modeling, such as the neurocomputational theory of cognitive aging proposed by Shu-Chen Li and colleagues (e.g., S.-C. Li & Lindenberger, 1999; S.-C. Li, Lindenberger, & Sikström, 2001; S.-C. Li, Oertzen, & Lindenberger, 2006, 2007) has facilitated conceptual integration of empirical findings and concepts from a wide range of behavioral and neuronal research traditions, and provides a theoretical basis for major portions of the Center's research program.

Proposition 3: The Exploration of Age-Graded Differences in Behavioral Plasticity is a Powerful Tool for Identifying Mechanisms of Development

Behavioral plasticity, or the alteration of developmental trajectories through experience, is a precious phenomenon. This statement holds both from scientific and societal perspectives. Scientifically, inquiries into the plasticity of human behavior are a rich source of developmental information. Through the assessment of "changes in change," they offer the promise to observe the operation and proximal consequences of developmental mechanisms. In particular, cognitive intervention studies, in which research participants of different ages are instructed and trained to perform one or more cognitive tasks, come with important validity benefits such as (a) an increase in experimental control; (b) the identification of age differences near asymptotic performance levels; and (c) the assessment of transfer and maintenance effects. If neurochemical, neuroanatomical, or neurofunctional imaging measures are assessed before, during, and after training, intervention studies also offer new insights into relations between behavioral and neuronal levels of plasticity. Thus, by partly taking control over behavior–environment interactions, the mechanisms of learning can be studied in the context of maturation and senescence. When longitudinal information is available, intervention studies bridge the gap between short-term alterations in performance and long-term developmental trajectories (e.g. Singer, Lindenberger, & Baltes, 2003; see below).

From the larger perspective of societal evolution, cognitive intervention studies explore the range of possible development, or what could be possible in principle if conditions were different. The resulting knowledge about the plasticity of developmental trajectories is essential for improving human welfare. Hence, investigations of age changes in the plasticity of development carry the potential to explain and ameliorate human development. For these reasons, age-comparative intervention studies with a focus on behavioral and neuronal manifestations of plasticity are the foundation stone of empirical research at the Center for Lifespan Psychology.

Overview of Research Projects at the Center for Lifespan Psychology

The empirical and conceptual work at the Center for Lifespan Psychology is currently structured into seven research projects, or teams of scientific investigators (see Table 1). The research activities pursued in these projects cover a wide array of developmental topics. To provide a few examples for illustration, recent studies have addressed the following questions: (a) How do relations between body and mind change from childhood to adulthood, and from adulthood to old age? (b) How and why do functions such as intelligence and memory vary within and across individuals, and how and why do they change with age? (c) How and to what end do individuals acquire and maintain a sense of personal control? How do they plan and manage their lives? (d) How do aging individuals cope with rapid technological change, and how can human engineering technologies facilitate the transition to old age? (e) How do young children learn to coordinate their behavior with others, and how does interpersonal action coordination affect social and cognitive development?

In addition to these research projects, the Center also hosts the independent junior research group of Martin Lövdén, who won the Sofja Kovalevskaja Award of the Alexander von Humboldt Foundation in 2006. In collaboration with colleagues from the Center, Martin Lövdén is using the four-year research funds associated with this award to investigate adult age differences in the plasticity of brain and behavior, with a special focus on spatial navigation and working memory, including their relations to mediotemporal and prefrontal brain regions.

In the following, two projects of the Center will be presented in greater detail, with an eye on the guiding propositions delineated in the previous section.

Research Project 1: Intra-Person Dynamics Across the Lifespan

The unifying theme of this project is to develop theories and research designs that articulate behavioral and neuronal development across timescales and levels of analysis. This emphasis requires a drastic increase in observation density within individuals, following Cattell's (1952) plea to gather multivariate observations not only within occasions across persons, but also within persons across occasions. A related theme of the project is to examine age differences in the plasticity of cognitive functions, such as episodic memory, from middle childhood to old age.

Types of Intra-Person Variability

In examining relations between short-term variability and long-term age changes or age differences, behavioral variability can be classified by its function (S.-C. Li, Huxhold, & Schmiedek, 2004). One may distinguish among plasticity, diversity, adaptability, fluctuation, and temporal coupling. *Plasticity*, in this context, refers to various forms of adaptive performance alterations, such as learning induced by instruction, practice, and training (cf. Baltes & Kliegl, 1992; Singer et al., 2003). *Diversity* refers to variations in responses to environmental demands, such as exploration of behavioral strategies during initial phases of complex skill acquisition (e.g., Lautrey, 2003; Siegler, 1994). *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). *Processing fluctuation*, or lack of processing robustness (e.g., S.-C. Li, Huxhold, & Schmiedek, 2004; S.-C. Li, Lindenberger et al., 2004), reflects stochastic fluctuations around a modal response. Processing fluctuations can be observed more easily when the functional value of other forms of variability is low to begin with, as is often the case for standard reaction time tasks, or when the functional values has been reduced, as is the case when individuals have consolidated the use of a particular strategy and are operating near maximum levels of functioning. Finally, *temporal coupling* refers to associations between two or more forms of processing within or across domains of functioning, such as concurrent covariation, lead–lag relations, and synchronization, at identical, different, or hierarchically nested timescales.

Exploring Age Differences in Fluctuations and Across-Domain Couplings: The 45-Days Study

A first micro-longitudinal study covering 45 daily measurement occasions compared adult age differences in intra-person fluctuations in four domains of functioning: postural control, spatial working memory, positive and negative affect, and task-specific motivation. Eighteen young adults (20 to 30 years of age) and 19 older adults (70 to 80 years of age) participated in the study across nine weeks. With respect to cognitive and sensorimotor functions, older adults showed greater intra-person fluctuations than younger adults. For instance, older adults' reaction times in a spatial working memory task had a higher mean and a wider distribution than younger adults' reaction times, and varied more from day to day in older adults than in younger adults.

The study also examined whether intra-person fluctuations in sensorimotor function (e.g., postural control) and cognitive function (e.g., spatial working memory) are more strongly coupled in older than in younger adults. Individuals who fluctuated more in postural control (i.e., older males) showed stronger couplings between daily fluctuations in postural control and daily fluctuation in working memory than individuals who fluctuated less in postural control (Huxhold, 2007). In contrast, with respect to emotional functions, older adults showed significantly less day-to-day fluctuation in positive and negative affect than younger adults (Röcke, 2006). Though this pattern is consistent with the hypothesis that emotion regulation improves with advancing adult age (Carstensen, 1993), alternative explanations such as age-linked differences in social contexts or arousal cannot be ruled out.

Comparing Within-Person with Between-Person Structures of Cognitive Abilities: The 100-Days Study

In a second study, 100 younger (20–30 years) and 100 older (65–80 years) adults participated in 100 daily sessions, working each day on a set of twelve cognitive tasks, comprising perceptual speed, episodic memory, and working memory. Self-report measures of affect, motivation, and mood were also assessed on a daily basis (Dissertation Annette Brose). In addition, all participants completed comprehensive pretests and posttests, with baseline measures of cognitive abilities, and transfer tasks for the practiced abilities. A subsample of younger and older participants also took part in structural and functional magnetic resonance imaging sessions and electroencephalographic recordings at pretest and posttest. Data collection will be completed in summer 2007.

The data of this study will, for the first time, permit researchers to systematically examine differences and commonalities between covariance structures of intellectual abilities measured either (a) across individuals at a given occasion or (b) across occasions within a given individual. Most existing research and theorizing on cognitive abilities assumes that covariance structures based on between-person differences generalize to intra-person structures (e.g., the ergodicity assumption; cf. Molenaar, in press). Surprisingly, it is not yet known whether ability structures representing between-person differences are good approximations of ability structures representing day-to-day variations in cognitive performance within individuals. To find out about this issue, developmental researchers need to abandon a quid-pro-quo research practice, in which between-person differences stand in for within-person variations (cf. Lindenberger & Oertzen, 2006).

To complicate matters, the degree of congruence between within-person structures and between-person structures may vary by age. For instance, given that alterations in cognitive functioning among older adults reflect variable combinations of age-related, pathology-related, and death-related mechanisms (e.g., Ghisletta, McArdle, & Lindenberger, 2006; cf. Sliwinski, Lipton, Buschke, & Stewart, 1996), the average similarity of the within-person structures of old adults to the between-person structures of old adults may be smaller than the average similarity of the within-person structures of young adults to the between-person structure of young adults. For related reasons, the study will also shed new light on the dedifferentiation hypothesis of old-age intelligence (cf. Lövdén & Lindenberger, 2005). According to this hypothesis, increasing correlations among cognitive abilities with advancing age reflect the operation of domain-general resource limitations. The critical question here is whether earlier observations of increasing correlations among cognitive abilities with advancing age, when assessed across persons (e.g., S.-C. Li, Lindenberger et al., 2004), are matched by increasing correlations among cognitive abilities with advancing age, when assessed within persons across days. Extending this question to the neuronal level of analysis, we can ask whether older individuals who show low levels of average performance and high correlations among different cognitive abilities tend to be those who show diffuse cortical activation patterns relative to older individuals with high average levels of performance and low correlations among cognitive abilities.

Lifespan Age Differences in Plasticity and Components of Episodic Memory Performance

Another part of the Intra-Person Dynamics Project examines lifespan age differences in the plasticity and components of episodic memory performance. Lifespan age differences in episodic memory plasticity were investigated in an initial multi-session memory training study involving younger children (9–10 years, *n* = 23), older children (11–12 years, *n* = 27), younger adults (20–25 years, *n* = 29), and older adults (65–78 years, *n* = 29; Brehmer, Li, Müller, Oertzen, & Lindenberger, in press; Brehmer, 2006). Participants in all age groups were instructed and trained in a simplified variant of the Method of Loci, an imagery-based mnemonic strategy (Baltes & Kliegl, 1992). Thus, the study provided, for the first time, a direct comparison of plasticity in episodic memory performance from middle childhood to old age.

The main results are shown in Figure 3. Individuals in all age groups benefited from mnemonic instruction and training. At the same time, substantial age differences in gains were observed. Older adults showed instruction-related performance gains, but they did not profit much from further training and practice. In contrast, younger children initially showed smaller instruction-related performance gains but considerably larger practice-related gains than older adults. The observed plasticity advantage of middle childhood over late adulthood provides predictions on lifespan changes in behavioral plasticity (cf. Lindenberger, 2001). To examine lifespan age differences in the maintenance of skilled memory performance, a longitudinal follow-up study was carried out 11 months after termination of the first study (Brehmer et al., 2006). Whereas both younger and older adults were able to maintain their level of performance over the 11-month period, younger and older children actually improved their memory performance beyond originally attained levels. Probably episodic memory plasticity in middle and late childhood reflects a powerful coalition between learning and maturation, allowing children to improve their level of skill in the absence of further practice.

The next step in this part of the project is to arrive at more process-oriented (mechanistic) explanations of lifespan differences in episodic memory performance (Dissertations Yee Lee Shing and Markus Werkle-Bergner). As a first approximation to this end, we currently distinguish between strategic and associative components of episodic memory. The strategic component refers to the selection, organization, and elaboration of episodic features during encoding and retrieval (Dunlosky, Hertzog, & Powell-Moman, 2005). In contrast, the associative component refers to mechanisms that bind features into a coherent memory representation (cf. Naveh-Benjamin, 2000). 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 adolescence and young adulthood. In contrast, the associative component, which primarily involves mediotemporal structures, is assumed to be fully functional in middle childhood, so that differences to younger adults in this component should be small.[1]

Neuromodulation of Neurocognitive Dynamics

In collaboration with the Berlin Neuroimaging Center, the goal of this large-scale study is to investigate the relationship of three factors known to influence dopaminergic neuromodulation: aging, the Catechol-O-Methyltransferase (COMT) gene polymorphism, and pharmacological intervention (Goldberg & Weinberger, 2004). Effects will be observed in neuromodulatory consequences on cognitive performance and brain activation patterns (Dissertation Irene Nagel). Our main question is whether lower dopamine (DA) levels associated with aging and the val/val allelic variant of the COMT polymorphism act additively or interactively in yielding more diffuse brain activations that underlie cognitive deficits. A related aim is to determine whether certain age-COMT allele combinations (i.e., older low-DA val/val carrier) respond positively to D-amphetamine (i.e., more efficient neural activations and improved cognition), whereas others (i.e., younger high-DA met/met carrier) respond negatively, reflecting the inverted U-shaped DA–cognition relationship expected on the basis of the neurocomputational theory proposed by Shu-Chen Li and colleagues (S.-C. Li & Sikström, 2002).[2]

Research Project 2: Sensorimotor–Cognitive Couplings

This project investigates lifespan changes in interactions between sensorimotor and cognitive aspects of behavior (Schaefer et al., 2006). 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, or maintaining one's balance on a bus while trying to read an advertisement. Everyday observation suggests that older adults, and young children, need to invest more attention into sensorimotor aspects of their behavior than teenagers and young adults. For example, 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 may affect younger adults' conversation to a lesser extent. How do individuals of different ages adapt to these multiple demands and their changes across situational contexts? Which are the exact processes involved in the increased demands of sensorimotor behavior on cognitive control? The focus of this project is on answering these questions by studying sensorimotor and cognitive behavior in multiple-task settings that have a high degree of everyday validity. Thus, the project studies age differences in the interaction between cognitive and sensorimotor domains of functioning, under the guiding proposition that the focus on age changes in across-domain links permits a better understanding of both domains and the system they form.

Dual-Task Costs in the Domain of Walking

In an early study we demonstrated that older adults invest considerable cognitive resources to attenuate the adverse consequences of sensorimotor decline (Lindenberger, Marsiske, & Baltes, 2000). Participants from three age groups were instructed to walk on narrow tracks while memorizing word lists. Speed and accuracy of walking were reduced when participants had to simultaneously walk and memorize, particularly in older adults. Relative to young adults, older adults also showed more pronounced performance reductions in memory performance when walking on the track while encoding to-be-remembered words than when standing or sitting (see also K. Z. H. Li, Lindenberger, Freund, & Baltes, 2001).

Recent studies further examine the apparent quandary of increasing cognitive control demands of sensorimotor functioning and decreasing efficiency of relevant control operations in the domain of spatial navigation. To this end, the project developed a virtual environment paradigm with a walking component. A scenario designed to give participants the impression of walking through, for example, an art museum or a zoo, 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 a museum to the bistro. The project's laboratory also features an advanced motion capture system with synchronized assessment of electroencephalic and electromyographic data. To visualize the participant's walking movements, markers reflecting infrared light are attached to the participant's body. Cameras capture the position of the markers, and the positions of the markers are post-processed offline according to biomechanical models.

The first study with this paradigm (Lövdén, Schellenbach, Grossman-Hutter, Krüger, & Lindenberger, 2005) tested the 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 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 (see Figure 4). Also, walking with navigation load increased older adults', but not younger adults', trunk-angle variability. Thus, in line with our hypothesis, reducing the attentional demands of walking by means of an assistive device enhanced the navigation performance of older adults, whereas young adults' navigation performance remained unaffected. In sum, the sensorimotor and cognitive domains of functioning are more tightly coupled in old age (see Schaefer et al., 2006, for review).

A Closer Look at Sensorimotor–Cognitive Interactions

Recent findings from our Center suggest that sensorimotor performance may actually be enhanced by concurrent administration of an easy cognitive task (Huxhold, Li, Schmiedek, & Lindenberger, 2006). Presumably, cognitive activities of lower difficulty promote an external focus of attention that allows the motor system to self-organize more easily. In contrast, higher levels of cognitive task difficulty may hamper motor control performance through cross-domain resource competition, in line with the walking studies reported above. The point at which performance improvements due to the first process are surpassed by decrements induced by the second process is likely to depend on both the individuals' sensorimotor and cognitive resources and actual task demands. In the meantime, this line of reasoning has been confirmed in a new series of experiments with children, young adults, and old adults (Lövdén, Schaefer, Pohlmeyer, & Lindenberger, 2007; Schaefer, Lövdén, Wieckhorst, Pohlmeyer, & Lindenberger, 2007; see also Dissertation Julius Verrel).

Intelligent Assistive Technology

In another series of experiments, we have begun to examine the effects of assistive technology on spatial navigation while walking (Dissertation Michael Schellenbach). To enhance older adults' walking stability as well as their ability to find their way in the environment, the marginal resource gain of assistive spatial navigation devices must be positive; that is, these devices need to consume less cognitive resources for their operation than they release (Lindenberger & Lövdén, 2006). The larger context of this applied work is to specify and implement psychological criteria for the design of effective assistive technology, with a special consideration of age-graded changes in cognitive and sensorimotor abilities. By continuously adjusting the balance between "environmental support" and "self-initiated processing" (Craik, 1983) in person-specific and aging-sensitive ways, intelligent assistive technology can promote successful aging by enhancing cognitive resource allocation. Furthermore, intelligent assistive technology may foster the generation of formerly latent cognitive resources by activating developmental reserves. Thus, assistive technology may play an important role in plasticity and serve as model case for studying behavior–brain–environment interactions.

Research Context and Cooperation

In this article, we have sketched the conceptual agenda of the Center for Lifespan Psychology, and provided a selective overview of its on-going research activities. In conclusion, we would like to note that much of the work at the Center is carried out in cooperation with researchers from the other research units of the institute, from other institutions in Berlin and Potsdam, and from other institutions around the world. Of the numerous collaborations in graduate training and research that include or have been initiated by other institutions in Berlin and Potsdam, we would like to mention: (a) the International Max Planck Research School "The Life Course: Evolutionary and Ontogenetic Dynamics" (LIFE), which includes the Max Planck Institute for Human Development, the Free University, the Humboldt University, the University of Michigan, and the University of Virginia; (b) the Berlin School of Mind and Brain, which is housed at the Humboldt University; (c) the Berlin NeuroImaging Center, a joint initiative by the Charité Universitätsmedizin Berlin, the Humboldt University, the Free University, the Physikalisch Technische Bundesanstalt, and the Max Planck Institute for Human Development; and (d) the Cooperative research unit on *Conflicts as Signals in Cognitive Systems*, which is funded by the Deutsche Forschungsgemeinschaft and co-ordinated at the Humboldt University.

Finally, we would like to express our special gratitude to the neighboring universities in Berlin and Potsdam, in general, and the psychology departments of the Free University, the Humboldt University, and the University of Potsdam, in particular. The three psychology departments are the institutions at which most of the Center's student research assistants are enrolled, from which most of the Center’s predoctoral students receive their doctoral degree, and at which most of the Center’s scientific staff are invited to teach their seminars and lectures. If the research projects of the Center have been productive and the careers of its students, predoctoral fellows, and research scientists successful, then the neighboring universities deserve much of the credit.

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Footnotes

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Table 1

The Center for Lifespan Psychology at the Max Planck Institute for Human Development: Overview of Research Projects

Name of Project	Scientific Investigators[a]	Selected Publications
Intra-person dynamics across the lifespan	Shu-Chen Li**; Christian Chicherio*, Oliver Huxhold*, Martin Lövdén, Viktor Müller, Florian Schmiedek, Timo von Oertzen, Ulman Lindenberger	Brehmer, Li, Müller, Oertzen, & Lindenberger (in press) S.-C. Li, Lindenberger, & Sikström (2001) Lindenberger, Li, & Bäckman (2006)
Sensorimotor-cognitive couplings	Martin Lövdén**; Sabine Schaefer, Ulman Lindenberger	Lindenberger & Lövdén (2006) Lövdén, Schellenbach, Grossmann-Hutter, Krüger, & Lindenberger (2005) Schaefer, Huxhold, & Lindenberger (2006)
The Berlin Aging Study (BASE)	Ulman Lindenberger**, Julia Delius Martin Lövdén, Jacqui Smith	Gerstorf, Lövdén, Röcke, Smith, & Lindenberger (in press) Ghisletta, McArdle, & Lindenberger (2006) Lövdén, Ghisletta, & Lindenberger (2005)
Developmental regulation: The interplay of motivation, affect, and cognition	Michaela Riediger**; Natalie Ebner*, Shu-Chen Li, Viktor Müller, Sabine Schaefer, Ulman Lindenberger	Ebner, Freund, & Baltes (2006) Riediger & Freund (2006) Riediger, Li, & Lindenberger (2006)
Interactive brains, social minds	Ulman Lindenberger**; Franziska Kopp*, Shu-Chen Li, Viktor Müller, Michaela Riediger	Anokhin, Müller, Lindenberger, Heath, & Myers (2006) Drewing, Aschersleben, & Li (2006) Striano, Kopp, Grossmann, & Reid (2006)
Toward a psychological and developmental theory of Sehnsucht (life-longings)	Paul Baltes** (until November 2006); Susanne Scheibe*	Baltes (in press) Scheibe, Freund, & Baltes (in press) Scheibe, Kunzmann, & Baltes (in press)
Formal methods and theory in lifespan psychology	Timo von Oertzen**; Shu-Chen Li, Ulman Lindenberger	Hertzog, Lindenberger, Ghisletta, & Oertzen (2006) S.-C. Li, Oertzen, & Lindenberger (2006) Oertzen (2006)

Note. The table refers to projects and project members as of fall 2006; for updates, visit www.mpib-berlin.mpg.de.

[a] Pre-doctoral fellows are not listed in this table.

**principal investigator; *post-doctoral fellow

Figure Captions

Figure 1. Environment and brain as antecedents and consequents of moment-to-moment variability and long-term changes in patterns of behavior. Lifespan changes in brain–behavior mappings are shaped by interactions among processes related to maturation, learning, and senescence. The identification of key players in the ontogeny of brain–behavior dynamics requires a coalition between formal tools for synthesis across levels of analysis and timescales, as well as empirical methods for studying variability and change in brain and behavior. Adapted from Lindenberger, Li, and Bäckman (2006).

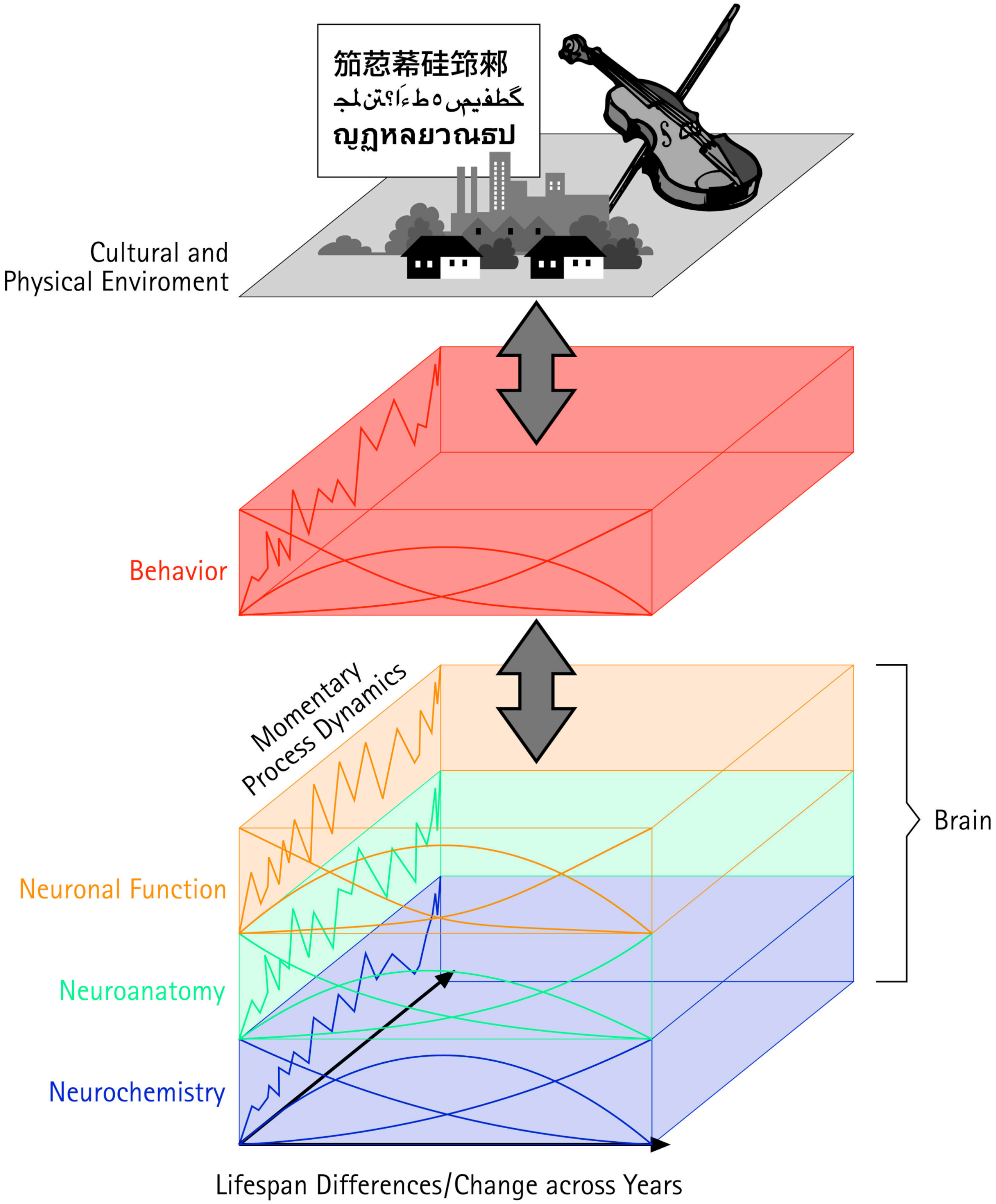
Figure 2. Example for predictions linking moment-to-moment variability to long-term change, and brain changes to behavioral changes. Senescent changes in neuromodulation lead to greater moment-to-moment fluctuations in neural signaling, enhance the prominence of background noise, reduce the distinctiveness of processing pathways and representations, and increase variability of cognitive performance. Aging individuals with greater moment-to-moment process fluctuations at a given point in time are expected to show greater subsequent longitudinal decline in mean levels of functioning than individuals who fluctuate less. Recent empirical evidence supports this prediction (Lövdén et al., 2006). Adapted from Lindenberger, Li, and Bäckman (2006).

Figure 3. Plasticity of episodic memory performance from middle childhood to old age. Age differences before instruction, after initial instruction, and after multi-session practice and training. Post-instruction scores for younger adults cannot be interpreted because of ceiling effects; all other data points are interpretable. Adapted from Brehmer et al. (in press).

Figure 4. Adult age differences in way-finding (spatial navigation) performance are shaped by sensorimotor demands. Bars display the mean distance covered to criterion as a function of age group (young and older adults) and walking demand (with or without handrail support). Provision of a handrail does not alter the way-finding performance of the younger adults, but

considerably improves the way-finding performance of the older adults. Adapted from Lövdén et al. (2005).

Figure 1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گطفيمں ٥ طءاَ؟تن لمج
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Cultural and
Physical Enviroment
Behavior
Momentary
Process Dynamics
Neuronal Function
Neuroanatomy
Neurochemistry
Brain
Lifespan Differences/Change across Years

Figure 2

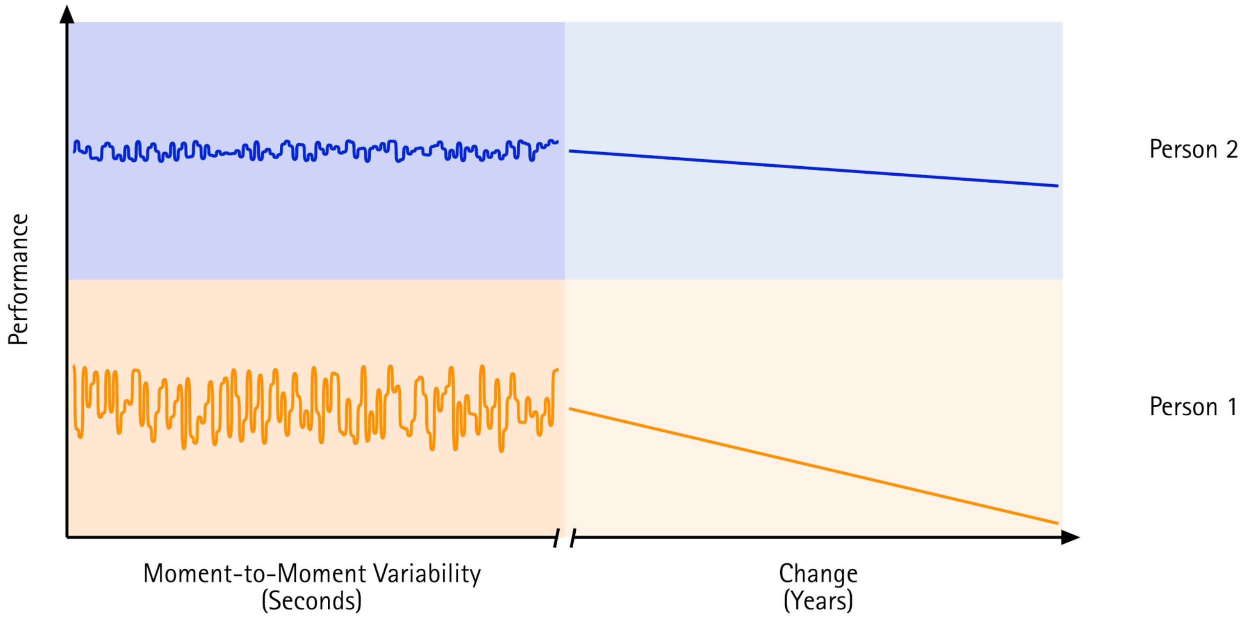
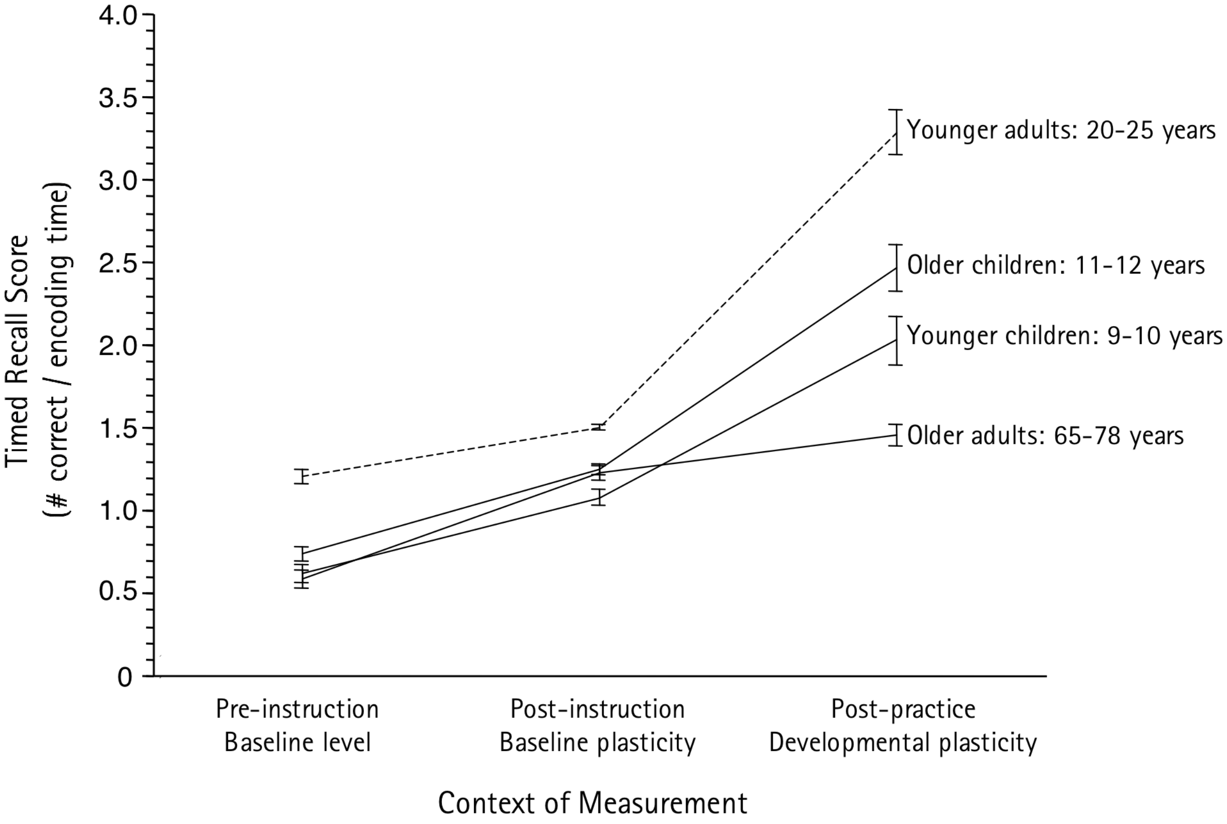

Performance
Person 2
Person 1
Moment-to-Moment Variability
(Seconds)
Change
(Years)

Figure 3


4.0
3.5
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2.0
1.5
1.0
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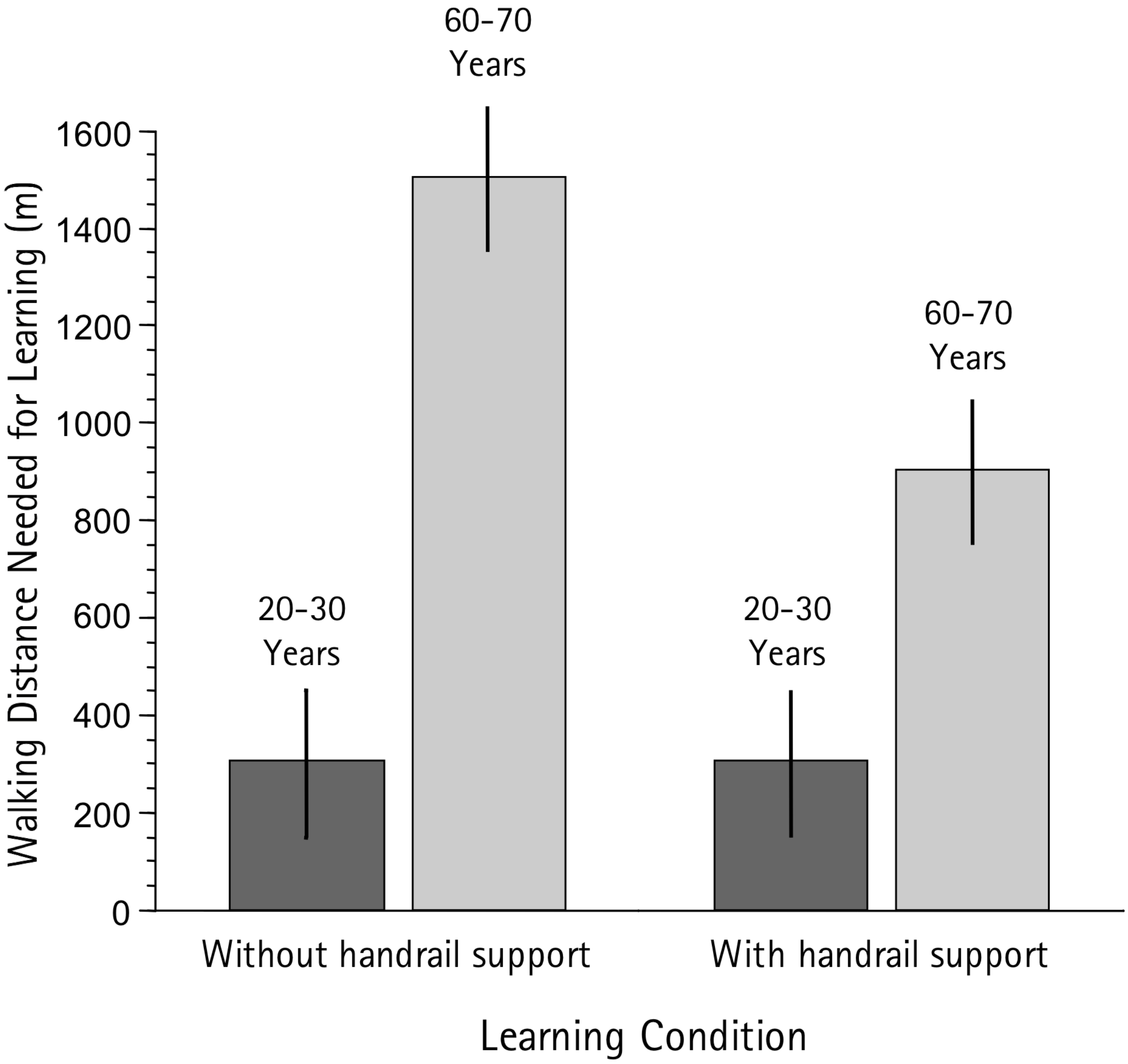
0
Timed Recall Score
(# correct / encoding time)
Younger adults: 20-25 years
Older children: 11-12 years
Younger children: 9-10 years
Older adults: 65-78 years
Pre-instruction
Baseline level
Post-instruction
Baseline plasticity
Post-practice
Developmental plasticity
Context of Measurement

Figure 4


60-70
Years
60-70
Years
20-30
Years
20-30
Years
Walking Distance Needed for Learning (m)
1600
1400
1200
1000
800
600
400
200
0
Without handrail support
With handrail support
Learning Condition