

V DISCUSSION

This discussion chapter consists of four major sections. First, the central findings of the present study are summarized and embedded into previous research and lifespan meta-theoretical proposals. Second, the limitations of the present investigation of questions about heterogeneity and differential development in old age are considered. The third section discusses at length the unique insights into heterogeneity and differential development that were gained from applying a systemic-wholistic approach. Finally, inferences and implications for future research are outlined.

5.1 Summary of Main Findings and Their Relation to Previous Research

The central objective of the present dissertation study was to examine questions about heterogeneity and differential development in old age from a systemic-wholistic perspective (e.g., Magnusson, 1996). I proposed that opting for an approach that explicitly focuses on studying structural and functional interdependencies among various psychological domains might provide insights that complement what is known from research that is more function-, element-, and mechanism-specific. Lifespan scripts about the contexts of developmental change at the macro-level, the evolutionary and ontogenetic foundations of change, and the complex nature of these changes (for overview, see P. B. Baltes et al., 1998) were used as an organizing principle to generate questions about profiles of psychological functioning in old age, enduring changes in these profiles over time as well as underlying mechanisms and outcomes. These questions reflect the three major objectives of lifespan research on heterogeneity and differential development (see Section 1.2.1). Table 20 summarizes the specific questions, expectations, and findings of the present study.

The first set of questions was aimed at the identification of heterogeneity in psychological functioning in old age and its correlates. Heterogeneity was operationally defined at a systemic-wholistic level as subgroups, which manifest different profiles of psychological functioning. Following previous cross-sectional work from BASE (Smith & Baltes, 1997), cluster analysis was used to identify three subgroups of individuals at baseline assessment of the 6-year longitudinal BASE sample. The subgroups differed in their profiles of scores across multiple domains of psychological functioning: Cognition, personality and self-related functioning, and social integration. As expected (and as a function of sample selectivity effects), the subgroups identified in the present study primarily reflected various desirable profiles. Participants from the less desirable profile subgroups identified previously in the

total BASE sample did not continue longitudinally, for the most part because of death or poor health. Despite positive selection, the subgroups extracted from this longitudinal BASE sample represented sufficiently distinct entities in their psychological profiles. They were also differentiated by a set of cross-disciplinary constructs (age, gender, biological, and environmental factors) that represented past and current contexts of development. Because the constructs were external to the definition of the subgroups, these differences are one illustration of the validity and meaningfulness of the three subgroups identified.

The second set of questions examined differential development in psychological functioning over time and its underlying mechanisms. At the level of subgroup membership, relative stability was preserved in that about two thirds of the longitudinal participants remained in their subgroups over time. At the level of the subgroup-defining profiles, the subgroups differed in their vulnerability to functional decline and this decline differed across the psychological domains. Based on notions about qualitative transitions in old age (e.g., Birren, 1959), it was expected that subgroups with less functional/desirable psychological profiles would be most at risk for decline. BASE data revealed only limited evidence for this proposal. In general, age, gender, and biological factors played a minor role in determining subgroup change over time. Additional individual-level analyses indicated that BASE participants who changed subgroup membership status over time reflected an additional aspect of differential development in old age.

The third set of questions addressed outcomes of heterogeneity and differential development in old age. Specifically, subgroup differences in psychological profiles and change over time were linked to subjective and objective outcomes of successful aging (P. B. Baltes & Baltes, 1990; Rowe & Kahn, 1997; Ryff & Singer, 1998). In support of the hypotheses, subgroups with more functional/desirable psychological profiles reported higher well-being over time and also lived longer after the end of the study period than did the less desirable profile subgroups.

This dissertation study attempted to explore some prototypical questions of developmental lifespan psychology such as the extent to which individuals and subgroups show common or differential developmental trajectories over time. The focus was on developmental change in old age because much less is known about this phase of life than about earlier life phases. Old age also provided a context to elaborate some of the conceptual and methodological difficulties involved in the study of heterogeneity and differential development. For example, the interpretation of the current findings is conditioned by issues of differential

sample attrition and the time intervals in-between measurement occasions. The present study demonstrated that combining a lifespan perspective with a systemic-wholistic approach contributes to furthering our understanding of the nature and diversity of development in old age, the changing biological and environmental opportunities and constraints that shape individual development, and the potential late-life outcomes of development. The systemic-wholistic approach thus represents a heuristic tool to examine questions about structural and functional interdependencies among psychological, biological, and environmental domains and hence complements more function-oriented research. Below follows a detailed review of the current findings to embed them into the conceptual and empirical literature.

Table 20

Overview of Central Research Questions and Main Findings

Research Questions	Supported by Results?
Identification and Description of Heterogeneity and Its Correlates:	
<i>Subgroup Differences in Psychological Profiles and External Correlates at Baseline</i>	
Q _{1a} Because of differential sample attrition, subgroups identified in the 6-year longitudinal BASE sample are expected to primarily represent various profiles of desirable psychological functioning rather than less desirable functioning.	Yes
Q _{1b} At baseline, subgroup membership is expected to be differentiated by age, gender, biological, and environmental factors.	Yes
Differential Development Over Time and Its Underlying Mechanisms:	
<i>Subgroup Differences in Change of Psychological Profiles Over Six Years and the Role of External Correlates</i>	
Q _{2a} Stability in subgroup membership over time is expected, but the subgroups show differential stability and decline in the profile-defining measures.	Yes
Q _{2b} Over time, subgroups with less functional/desirable psychological profiles are expected to be most at risk for functional decline. In addition, age, gender, and biological factors are expected to predict subgroup change over time.	Partially
Outcomes of Heterogeneity and Differential Development Over Time:	
<i>Consequences of Subgroup Differences in Psychological Profiles and Change Over Six Years</i>	
Q _{3a} Subgroups with more functional/desirable psychological profiles are expected to report higher well-being over time than less desirable profile subgroups.	Yes
Q _{3b} Subgroups with more functional/desirable psychological profiles are expected to live longer than less desirable profile subgroups.	Yes

5. 1. 1 Identification and Description of Heterogeneity in Old Age and Its Correlates

Heterogeneity is of major interest to lifespan developmental researchers because it can be considered to represent one outcome of the multidimensionality and multidirectionality of developmental processes across the life course (P. B. Baltes, 1987; Birren & Cunningham, 1985; Busse, 1969; Lerner, 1986; Schaie, 1996). A conjoint consideration of communalities and differences between individuals helps to better understand the potentials and limits of the malleability and plasticity of human development. Lifespan meta-theoretical frameworks about human development can be used to structure questions about the mechanisms underlying heterogeneity in psychological functioning (for overview, see P. B. Baltes et al., 1998). At one level, biological and environmental contexts of development can be considered as macro-contextual systems of influences including age-graded, history-graded, and idiosyncratic factors that conjointly produce regularities and differences in human development. At another level, the biocultural co-construction of development and its ontogenetic and evolutionary nature implies that heterogeneity prevails into very old age and may even be enhanced because different constellations of mechanisms may underlie development in very old age as compared with previous life phases.

To examine heterogeneity within a sample of participants in old and advanced old age, the present dissertation study used the methodological tool of cluster analysis to identify subgroups of individuals. Rather than using the total cross-sectional sample as done in previous person-oriented work from the Berlin Aging Study ($N = 516$; Smith & Baltes, 1997), the current dissertation restricted itself to those BASE participants who were longitudinal survivors after 6 years, on average ($n = 132$). This was done so that changes in the identification of subgroups could be examined over time. The subgroups were defined by the fact that (1) members of one subgroup shared communalities in baseline profiles across three different domains of psychological functioning, and (2) that the subgroups differed from one another in these profiles. Three subgroups were identified: an Overall-Positive Profile Subgroup, an Average-Profile Subgroup, and a Disparate-Profile Subgroup.

The decision to use cluster analysis as a tool has costs as well as benefits. One caveat is that any application of multivariate-structural techniques may produce but one of several possible outcomes (Hertzog, 1996). All classification approaches involve arbitrary criteria underlying minimum inter-group and maximum intra-group differences (Aldenderfer & Blashfield, 1984). Thus, other groupings of BASE participants also would have been possi-

ble¹ and the results are, of course, limited in generalization by the particular selection of measures and the sample studied. It was not the goal of the present study to provide a typology or taxonomy of older individuals, as has recently been attempted in research on personality types in young adults (e.g., Asendorpf, 2002; see also Block, 1971). The underlying rationale for many typological or taxonomic approaches is that entities grouped together represent naturally occurring groups that may or may not be qualitatively distinct. In the present study, instead, classification of older individuals into subgroups was simply based on similarities and dissimilarities in level and shape of the profile across the multivariate space of psychological dimensions. The usefulness of this particular bottom-up approach rests upon additional criteria (Aldenderfer & Blashfield, 1984; Milligan & Copper, 1987). In the context of the present study, these criteria were established at baseline assessment as well as in terms of change over time. At baseline assessment, it was demonstrated that the subgroups represent sufficiently distinctive entities in subgroup-defining measures (psychological profile). They also showed differential relationships to external validation measures (cross-disciplinary factors) and their profiles were conceptually similar to subgroups identified in previous person-oriented research.

The current study offered the unique opportunity to compare two subgroup classifications from different nested samples of the same study. On the one hand, this enables statements about the validity of the classification procedure. On the other hand, and perhaps more importantly in the context of research on heterogeneity and differential development in old age, it allows to extend previous selectivity research (e.g., Lindenberger et al., 2002; Rabbitt et al., 2004; Siegler & Botwinick, 1979) to an examination of selective attrition at a subgroup (or systemic-wholistic) level. As compared to the nine subgroups previously identified in the total cross-sectional BASE sample (Smith & Baltes, 1997), the three subgroups extracted from the 6-year longitudinal BASE sample at baseline assessment primarily represented various profiles of desirable psychological functioning rather than less desirable profiles. Already at this level, it was clear that there had been selective drop-out in BASE: Primarily participants who were assigned to the more desirable profile subgroups survived and continued in the study over six years. This selective drop-out might have resulted in a loss of heterogeneity at the subgroup level. This was found not to be the case. Despite this positive selection of the longitudinal BASE sample, the three subgroups identified exhibited heterogeneous profiles of functioning across different domains. Even though most of the individu-

¹ For the conceptual and methodological arguments underlying the selection of the three-subgroup solution, see Section 4.1.1.

als in the 6-year longitudinal sample were functioning at relatively high levels, there were differences at the subgroup level in profiles of successful aging.

The *Overall-Positive Profile* Subgroup showed high levels of functioning/desirability across a variety of different domains including psychological, physical-functioning, and life-history dimensions. According to the Rowe and Kahn model (1997; see also Section 1.3.4), this group's profile could be regarded as the 'ideal type of successful aging' because three defining components associated with health, cognition, and engagement with life were fulfilled. Members of this group apparently had low risks of disease and disease-related disabilities. They also were cognitively very fit in that their cognitive performance was more than three quarters of a standard deviation above the mean of the total cross-sectional BASE sample. In addition, subgroup members showed an active engagement with life, which can be tapped in BASE by using measures of social integration and extraversion (facets of gregariousness, positive emotionality and activity) as well as control beliefs and the time and effort people invested into 10 areas of life (goal investment). The fact that this group of persons comprised about half of the sample is indicative of the positive selection of the 6-year longitudinal BASE sample.

The *Average Profile* Subgroup was characterized by mean-levels or moderately positive functioning/desirability across psychological and physical-functioning measures. The only distinctive extreme was the major socio-economic disadvantage in that the life-history composite measure was about half a standard deviation below the mean of the total BASE sample and almost one standard deviation below both other subgroups. Subgroup members can be expected to have dealt with this macro-structural burden throughout their lives and it is thus interesting and astonishing that the burden was more or less *not* mirrored in their psychological and physical-functioning profile.² At a first glance, such patterning is not consistent with the large body of evidence from more function-oriented research that reports socio-economic constraints to be linked with higher risks for limitations in health and functional capacity (for review, see Adler & Snibbe, 2003). However, the cross-domain profile of functioning found among group members is in line with lifespan scripts about developmental

² Relatively low scores on knowledge and goal investment can reasonably be related to the socio-economic burden of subgroup members. Education has been consistently linked to cognitive status and particularly measures of culture-based knowledge structures (Schaie, 1996). Similarly, low income and low job prestige may restrict the economic opportunity structures to take part in cultural and social activities and thus, at least in part, account for relatively low goal investment. However, low life investment does not only result from low scores across various life domains, but also from many very low scores combined with some very high scores. It may thus be indicative of selection processes rather than relative disengagement and hence be adaptive under constraining life circumstances (P. B. Baltes & Baltes, 1990).

co-constructivism, which suggest that life-history factors are of decreasing importance in old age (P. B. Baltes et al., 1998). Based on the Rowe and Kahn model (1997), the psychological and physical-functioning profiles for members of this group could be categorized as 'normal' aging representing more or less average functioning in a locally representative sample of old adults. In face of the macro-structural hardships, the Average-Profile Subgroup can even be regarded to have aged robustly (successfully).

The *Disparate Profile* Subgroup showed a miscellaneous profile of functioning both on psychological and cross-disciplinary measures. On the one hand, their socio-economic benefits were reflected in superior cognitive performance suggesting that education and a complex work life may have been associated with lifelong intellectual activities such as reading, learning new skills, or active attempts to maintain skills, which in turn may have helped in maintaining cognitive functioning in old age (Pushkar et al., 1999; Schooler & Mulatu, 2001; but see Aartsen, Smits, van Tilburg, Knipscheer, & Deeg, 2002; Hultsch, Hertzog, Small, & Dixon, 1999). On the other hand, their health constraints and potentially associated behaviors (e.g., frequent doctor's appointment, compromised mobility, bitterness, and grief) can be assumed to have negative effects on maintaining one's social contacts and internal control beliefs, or even lead to increased neuroticism (for review, see Seeman, 2000). One could also argue the other way around in that certain aspects of personality and lack of social integration act as risk factors for developing diseases (Caspi et al., 1998).

At a first glance, the Disparate-Profile Subgroup appears to be an exception to the successful aging pattern suggested by Rowe and Kahn (1997) because subgroup members were not fully able to translate their socio-economic and cognitive benefits into an active engagement with life. However, this group was relatively older and contained numerically (but not statistically significant) more women and persons living alone, which represent factors that have all been linked to decreased quality of life in very old age (Johnson & Troll, 1992; Smith & Baltes, 1998). In addition, a qualification in the Rowe and Kahn model (1997) suggests that it is not only the presence, but also the severity of risk factors and diseases that is highly relevant for successful aging. Given that functional health was preserved and that the medically diagnosed health was still in the average range of the distribution in the total cross-sectional BASE sample, these diseases were not too severe and debilitating. Based on this line of argument, subgroup members reflect the broad category of normal aging or even a certain variant of successful aging, especially among current cohorts of oldest-old women.

They may also reflect the increased salience of biological factors in determining the outcomes of aging – or as P. B. Baltes (1997) argues, the incomplete architecture of ontogeny.

The three subgroups can be linked not only to lifespan scripts about differential development and to the successful aging criteria developed in the Mac Arthur Studies of Successful Aging (Rowe & Kahn, 1997), but also to previous person-oriented research using bottom-up strategies to identify subgroups of individuals in old age. For example, the Overall-Positive Profile Subgroup was relatively similar to Subgroup A and Subgroup C from the Gothenburg study (Maxson et al., 1996; see Section 1.3.4 for Table 1). These subgroups performed consistently at an above average level across the profile-defining measures of cognition, social contacts, well-being, physical health, and functional capacity. They also showed highly functional patterns on the validation measures in terms of low dementia incidence and prolonged survival. Similarly, the Disparate-Profile Subgroup was comparable to the Gothenburg Subgroup D because both showed a profile of cognitive fitness combined with more or less ample constraints in health, social integration, and well-being. In addition, the group's profile also was corroborated by findings from person-oriented research conducted in the context of the Seattle Longitudinal Study: Members of the socially-isolated subgroup had greater health problems (Bosworth & Schaie, 1997). For the Average-Profile Subgroup there was no direct association to groups from the Gothenburg study because the latter did not contain a subgroup with a profile that was consistently in the average range of functioning.

Of course, comparing profile consistencies across studies is hampered by sizeable differences in sample characteristics, measurement techniques, and clustering procedure. Among other differences, the Gothenburg sample was much younger than the BASE sample (Maxson et al., 1996). In the Gothenburg study, each participant was 70 years of age at study enrollment ($N = 335$) as opposed to a mean age of 85 years in the total cross-sectional BASE sample, which, in addition, was stratified by age and gender ($N = 516$). As a consequence, sample attrition linked to mortality and incapacity did not play so much of a role in the Gothenburg study: The Swedish 3-wave longitudinal sample followed over nine years was larger ($n = 170$) as compared to the 3-wave sample in BASE followed over six years ($n = 132$). Regarding the clustering procedure, Maxson and colleagues (1996) used both psychological and cross-disciplinary factors (rather than psychological measures only) to identify the subgroups. The authors also did not apply a two-stage clustering procedure (see Section 2.3.1 and Section 4.1.1), but took the outcome of the Ward's procedure for granted and determined

the optimal number of subgroups on the basis of maximal subgroup differences as indicated by a series of ANOVAs. Despite such ample differences, it is noteworthy that subgroups extracted from the two studies resembled each other reasonably well. Future research may profit from utilizing more rigorous methodological standards to determine the within- and between-study consistency of subgroups (e.g., independent replication across random halves of a given sample: Breckenridge, 1989; Schnabel et al., 2002).³

Theoretical conceptions of heterogeneity in old age suggest that age and gender may play a role. Selective mortality may contribute to a reduction in heterogeneity among the oldest old (i.e., only a positively selected group survives). In addition, the oldest-old men may be more positively selected than the very old women. On the other hand, the increased impact of biology and the decreased effects of culture to compensate (P. B. Baltes, 1997) suggests a reduction in heterogeneity and increased prevalence of dysfunction in the Fourth Age (see also Finch, 1996; Olshansky et al., 2001; Verbrugge, 1990). The present study revealed evidence convergent with the latter proposal. The relative risk of a less functional/desirable profile was higher for BASE participants older than age 85 than for younger individuals. These results are in line with epidemiological data suggesting that individuals in their late 80s were able to meet single components of a successful aging definition (e.g., functional health, basic cognitive abilities), but once they were required to simultaneously fulfill multiple criteria, prevalence rates of so-defined successful aging dropped steeply from 44% of participants in their early 70s to 8% among those in their late 80s (Jorm et al., 1998). The balance of gains and losses has turned to the negative. Convergent evidence provided by the present study gains even more in significance if one acknowledges that (a) the less desirable profile subgroups in the 6-year longitudinal BASE sample were, on average, at a higher functioning level than those in the total cross-sectional BASE sample and (b) the oldest old represent an increasingly positive selection of their birth cohort, as mentioned above.

Gender did not play a strong role in subgroup composition. This can be interpreted in the context of natural and sample-based selectivity effects. At the population level, mortality hazards for men are larger than for women. As a consequence, the 'structural' composition of samples of older men and women can be expected to differ in that men represent a more positive selection on factors that may be associated with longevity (Smith & Baltes, 1998). It is an open question, what these factors specifically are (Christensen & Vaupel, 1996) and it is also unclear to what extent selection effects contribute to, reduce, or cancel out observed

³ Due to sample size restrictions in the present study, it was decided not to use random split-halves to replicate the subgroups (see also Section 4.1.1).

differences between men and women. Sample-based selection and attrition effects associated with gender may have also played a role: Consistent with findings from North American studies (Gatz, Kasl-Godley, & Karel, 1996; Soldo, Hurd, Rodgers, & Wallace, 1997; Suzman, Harris et al., 1992), analyses of the total cross-sectional BASE sample reported disadvantages for women with regard to physical frailty, life conditions, and psychological functioning on 24 out of 30 constructs with effect sizes amounting to approximately half a standard deviation (Smith & Baltes, 1998; see Appendix D for Table D.1). In contrast, analyses of the 6-year longitudinal BASE sample showed that only 6 out of the 30 constructs yielded significant gender differences (see Appendix D for Table D.2). In essence, differential associations between gender and functioning obviously did not play a major role in the positively select 6-year longitudinal BASE sample and this was so at the level of the sample in total as well as at the subgroup level.

In sum, heterogeneity in a sample of individuals in old age could be identified, structured, and described by subgroup differences in profiles across multiple domains of functioning (Magnusson, 1996). Subgroup characteristics in the various domains can be interpreted on the one hand as the manifestation of differences in gain-loss dynamics and on the other hand as variations of bio-cultural ontogenetic processes. Because of the cross-sectional nature of baseline data, it cannot be ruled out to what extent profile differences between the subgroups have been present for many years or even the whole lifespan, or whether they were just recent phenomena. For example, it was not possible to examine whether the functional profiles were maintained from mid-adulthood or whether they represent the current state of ongoing decline processes from previously better functioning. The finding that the subgroups were also differentiated by a set of cross-disciplinary measures that represent past and current contextual factors for development (P. B. Baltes et al., 1998) suggests that these factors are involved in regulating the functional profiles of and membership within the subgroups. It seems safe to conclude that observed differences between the profile subgroups at baseline represent the conjoint outcomes of biogenetics of aging and different lifestyles and pathways that have led these subgroups into old age. The next step was to examine how the profile subgroups changed over a period of six years subsequent to study enrollment. The results provide substantive evidence that the subgroups continued to age differently during old age.

5. 1. 2 Differential Development Over Time in Old Age and Its Underlying Mechanisms

To examine questions about patterns of differential development in old age and its underlying mechanisms, analyses of stability and change over six years in BASE were carried out at the level of the subgroups and the level of the subgroup-defining measures. Examining stability and change at both the subgroup and the variable level allowed a conjoint consideration of the key assumptions of a person-oriented perspective: The approach enables the researcher to capture the dynamic and multivariate nature of human development, to examine interindividual and intraindividual differences, and to investigate the heterogeneity of developmental processes in old age (Lövdèn, Bergman et al., submitted).

The following sections are organized around the three questions about differential development examined. The first question was asked at the subgroup level and analyses indicated that about two thirds of the longitudinal BASE participants remained over time in those subgroups they were assigned to at baseline assessment. Those who moved to a different subgroup were found to show systemic decline and thus shed some additional light on facets of differential development in old age. The second set of analyses was carried out at the level of the profile-defining measures and results from three different methodological approaches converged to suggest that (a) the subgroups differed in their relative risk for functional decline and that (b) subgroup decline differed across the psychological domains. In a third step, potential mechanisms underlying subgroup change were addressed. Contrary to expectation, neither age, gender nor biological factors were found to have played a major role in determining differential change over time. In part, this finding was likely due to both the positive selection of the 6-year longitudinal BASE sample, but also to the relatively short time intervals between occasions.

5. 1. 2. 1 Stability and Change Over Time in Subgroup Membership

Conceptual as well as methodological arguments constituted the rationale underlying the examination of questions about stability and change over time in subgroup membership. To begin with, findings of relative stability in subgroup membership over time illustrate that individuals within a given group are simultaneous in the way they change over a certain period of time. That is, subgroup members share not only similarities in their profiles of functioning at a given point in time, but also in how these profiles change over time. Such relative stability underscores the validity of assigning individuals to subgroups and thus supports the systemic-wholistic approach (Manton & Land, 2000; Nesselrode, 1991). In this

way, stability can be considered to represent a normative constellation. If change in subgroup membership occurs, this can either be used to put the assignment procedure into question (Hair & Black, 2000; Milligan & Cooper, 1987) or it can be interpreted to represent an additional and valid aspect of differential development. In the latter case, subgroup transition may reflect non-normative (i.e., idiosyncratic) influences such as the onset of illnesses or outcomes of the incomplete architecture of human ontogeny especially in the oldest old (P. B. Baltes et al., 1998). Methodologically, this requires that subgroup transition can meaningfully be linked with other indicators or outcomes of differential development.

Previous analyses from BASE have compared cluster solutions identified in the total cross-sectional sample based on different sets of variables, but no BASE analyses have so far examined stability over time. Smith and Baltes (1998) compared group membership between their 11-group solution derived from 23 cross-disciplinary variables ($N = 508$) and the 9-group solution derived from 12 psychological variables ($N = 510$; Smith & Baltes, 1997). They reported that 68% of the BASE participants remained grouped together despite analyses using different cross-sectional measures. The current study adds to these cross-sectional results in several ways. To begin with, linking subgroups over time, which were derived from applying the same clustering procedure at different occasions in BASE, revealed a similar amount of stability over a period of four years with a two-year interval resulting in somewhat larger stability coefficients and a six-year interval in somewhat lower coefficients. Second, the subgroups were not found to be differentially vulnerable to membership instability and it was demonstrated that the same-subgroup pairs were significantly more stable than expected by chance, whereas most other transition possibilities between the subgroups were very unlikely to occur. Third, overall profile stability of the subgroups over time (as revealed by Cattell's pattern similarity index) was reasonably high, which indicates that the overall profile characteristics of level, shape, and scatter were relatively persistent over time.

Addressing questions about subgroup stability over time is an essential step because each and every classification approach is faced with concerns about state-dependency and is thus required to examine questions about the meaningfulness and substance of the person groupings. Short-term intraindividual variability has been suggested to be a stable and systematic individual difference characteristic, which may account for large portions of interindividual heterogeneity.⁴ In a very recent study, Nesselroade and Salthouse (2004), for exam-

⁴ In essence, research on short-term intraindividual variation can be regarded a key issue in systemic-wholistic thinking because variation is not considered to be measurement error, but a state-like characteristic of individuals that may help to better understand structural and functional relations within a given group of individuals

ple, demonstrated in perceptual-motor variables that intra-person variability amounted to between 37% and 53% of the total inter-person variability. This illustrates that classification approaches that are based on static rather than dynamic criteria are partly state- or episode-dependent (e.g., Nesselroade, 1991; Nesselroade & Ghisletta, 2000). Study designs most often involve few occasions that are relatively far apart rather than having available numerous occasions over relatively short periods of time (Lövdèn, Bergman et al., submitted; Nesselroade, 2001). Within the constraints of a large-scale longitudinal study with measurement intervals of several years, it is not possible to disentangle short-term fluctuations from long-term enduring changes. As a consequence, the current study used the data available to demonstrate that membership in the groups was reasonably stable over a period of several years.

Given the small sample size and the exploratory character of the present endeavor, the moderate *kappa* statistics found can be regarded appropriate (for using kappa statistics in research on personality prototypes, see Asendorpf & van Aken, 1999). When applying cluster analysis repeatedly at one point in time, the literature reports that a level of reallocation of around 20% is within the acceptable range (because it translates into a reliability coefficient of $r = .80$; see Smith & Baltes, 1997). In the present study, several years were in-between the occasions and long-term stability in group membership was, of course, also affected by test-retest stability of the single profile-defining constructs (Salthouse, 2004; see Section 3.2.1.3 for Table 6). Both construct stability and group membership stability over time were in an acceptable range. Hence, cluster analysis seems to be an efficient methodological tool in the context of the systemic-wholistic approach that allows to categorize individuals into subgroups that remain relatively distinct over time.

Temporal integrity of the groups over time can be interpreted to be an indication of the continuity of development in old age. It has to be cautioned, however, that the 6-year longitudinal BASE sample primarily encompassed individuals in their seventies and early eighties and less functional/desirable subgroups from the total BASE sample were noticeably under-represented. If more individuals in their late eighties or older were available for repeated assessment, it may have been possible to thoroughly examine whether intraindividual fluctuations in group membership over time are especially pronounced among oldest-old participants. For example, individuals older than age 85 years may be more likely to transit from a more functional/desirable profile subgroup to a less desirable profile group over time (e.g.,

(Nesselroade, 2001; for conceptions about stable patterns of situation-behavior relations in personality research, see Mischel & Shoda, 1995). The recent renaissance of this research agenda (e.g., child development: R. Siegler, 1994; Thelen, 1992; cognitive functioning: MacDonald, Hultsch, & Dixon, 2003; and affect: Eid & Diener, 1999) may also profit from more person-oriented inquiries.

from the Overall-Positive Profile Subgroup to the Average-Profile Subgroup). In contrast, young-old participants may be more likely to show subgroup stability or even move to a more functional group over time (e.g., from the Disparate-Profile Subgroup to the Average-Profile Subgroup).

Following-up longitudinally the stability of person groupings and their profile characteristics has rarely been done in the literature, so this study clearly adds to the field in this regard. Having demonstrated subgroup stability over time adds credibility to the quality of the cluster solution and illustrates that subgroup differences in functioning across a number of different domains found at one point in time relatively preserved over a period of six years. These findings also supported the decision to use subgroup membership at baseline assessment to examine subgroup differences in patterns of stability and decline in the profile-defining measures. Before discussing these results, an extra section is devoted to exploit BASE participants who changed subgroup membership over time as representing one facet of differential development (in old age).

Subgroup Movers. The present data revealed consistent evidence with the notion that subgroup transition represents an additional facet of differential development in old age. Subgroup transition can be interpreted in the context of lifespan scripts about macro-contexts of development (P. B. Baltes & Nesselroade, 1984) in that moving out of a given group of persons reflect non-normative events that were associated with rather idiosyncratic factors such as the onset of specific sets illnesses in old age. BASE participants who changed subgroup membership status over time were found to differ in various ways from those who remained in their subgroups. At baseline assessment, 'subgroup movers' were less similar to their baseline subgroups than were 'subgroup constants', they were older, and more impaired in health status. Over time, these participants were particularly change-salient in that they showed pronounced systemic decline across various domains of psychological functioning. In addition, the hazards of dying over a four-year period were doubled for BASE participants who showed subgroup transition as compared with those who were continuously assigned to the same subgroups. Taken together, follow-up analyses suggest that subgroup re-assignment over time followed meaningful and interpretable patterns rather than representing mere unreliability. A small group of 6-year longitudinal BASE participants showed systemic-wholistic decline and, associated with this, was vulnerable for subgroup transition, which in turn was accompanied by an elevated risk of death after the end of the study.

It is only possible to speculate about the underlying mechanisms. Consistent with lifespan scripts about the biocultural architecture of the life course (P. B. Baltes et al., 1998) and with proposals about qualitative transitions in advanced old age (Birren, 1959; Finch & Kirkwood, 2000; Verbrugge, 1994), one can argue that the biological system was the driving force underlying systemic decline and mortality, perhaps in terms of pathological and non-normative factors, but these were not assessed well in BASE. Health and sensory functioning, which represent proximal indicators of age-graded factors, were relatively impaired among ‘subgroup movers’, whereas no differences were found on life-history factors, and well-being also was maintained over time.

The very fact that, despite restrictions in sample size, the mortality difference turned out to be significant and robust to covarying out the effects other developmental-contexts variables exemplifies that the effect was ample in size. The predictive strength of a systemic-wholistic approach for further differential development in the future lies not only in level information about multiple domains of functioning, but also in information about systemic change. These are promising first results illustrating that a focus on cumulative change in addition to profile status information may be of special importance for research on successful aging outcomes (see also Bosworth et al., 1999 ; Jopp, Lißmann, & Smith, 2000). If larger samples are available, it is not only possible to replicate these findings, but also to further follow-up on groups of participants, which show distinct developmental trajectories such as pronounced decline or functional increase over time.

5. 1. 2. 2 *Stability and Change Over Time in Profile-Defining Measures*

Evidence for differential development and change can also be observed at the domain and variable levels. Individuals within subgroups may remain together over time, but the subgroups may show different patterns of change across domains. In essence, a particular profile may indicate more or less risk for change or maintenance of functioning in a domain. This is expected because inherent in the profiles of the subgroups at baseline was that differential gain-loss dynamics had played a role in determining functional status up to baseline assessment and would likely continue to underlie future change (Aldwin et al., 2001; P. B. Baltes et al., 1998; Dixon & Bäckman, 1995; Liang et al., 2003).

Subgroup membership at baseline assessment was utilized to investigate subgroup differences in risks for functional decline on the profile-defining measures over a period of six years. The three subgroups could not only be differentiated from one another by profile dif-

ferences at baseline assessment, but also by distinct patterns of stability and change over time. The subgroups maintained their baseline rank order of psychological functioning over time. Due to the specific patterns of stability and decline, the absolute amount of differences between the baseline subgroups got smaller over time. The following sections consider differential patterns of change in the context of regression artifacts, discuss their functional significance and relations to the literature, explore the systemic character of change, and address potentially underlying mechanisms.

Differential Change was Robust and Reliable. At the domain-level, there is a long-standing debate about the interpretation of change (for overview, see Campbell & Kenny, 1999; Nesselroade, Stigler, & Baltes, 1980; Rogosa, 1995). The onus of the researcher is to prove that findings are robust and reliable. To this end, quite some effort was invested to demonstrate that subgroup differences in change over time were robust and reliable rather than just a mere reflection of regression-to-the-mean artifacts. Regression towards the mean refers to the phenomenon that for a given score on x_1 , the corresponding mean score on x_2 is closer to the population mean of x_2 in standard deviation units than x_1 is to the population mean of x_1 in standard deviation units (Cronbach & Furby, 1970). Regression artifacts occur whenever a nonrandom sample from a population is measured on two variables that are imperfectly correlated, and regression can be expected to be stronger the more extreme a sample group is and the less correlated the variables are.

To guard against regression artifacts in change over time,⁵ multiple methodological tools were utilized: Results from the more traditional repeated measures ANOVAs were complemented by findings of event history analysis. This technique was pioneered by sociologists (e.g., Blossfeld, Hamerle, & Mayer, 1989) and it converts continuous change into discrete change by adjusting for whether the change observed has exceeded possible measurement error (Schaie, 1989). In a further step, multilevel growth curve models (for review, see Hertzog & Nesselroade, 2003; Lindenberger & Ghisletta, 2004) were used to estimate change trajectories over time and to demonstrate group differences therein.⁶ The three sets of

⁵ It is unlikely that regression artifacts have played a role in identifying the three profile subgroups at baseline assessment in the present study. The subgroups were derived from multivariate space of 11 constructs in total and their profiles were found to be multivariately extreme (e.g., peaks and lows in the Disparate Profile). From a regression point of view, it is unlikely to be classified as extreme based on one measure once a person has been classified as extreme based on another measure. Multivariate extremity due to regression artifacts would have been possible only in case of multicollinearity, but correlations among the profile-defining measures were of moderate size (see Section 4.1.1 for Table 9).

⁶ For a detailed description of these methods, the interested reader may refer to the Appendix for Section C.2.1.

analyses revealed convergent evidence. Conceptually, one may also argue against interpreting group differential change as regression artifacts. It was not the case that the same domains showed decline over time, but the picture was more complex. A given subgroup maintained functioning in one domain, but showed decline in others, and the same functional domain remained constant in some subgroups, but not in others. For example, the Disparate-Profile Subgroup showed cognitive decline, but stability in social integration, whereas members of the Overall-Positive Profile Subgroup showed the reversed pattern with decline in social integration and stability in cognitive functioning. Regression towards the mean is an issue threatening each and every attempt to examine change over time on a given set of measures (Campbell & Kenny, 1999). The approach taken herein is just *one* of several ways to deal with this fundamental question (see also P. B. Baltes, Nesselroade, Schaie, & Labouvie, 1972; Nesselroade et al., 1980). Based on this approach, it seems unlikely that subgroup differences in change over time as identified in the present study can completely be accounted for by regression artifacts.

Functional Significance of Differential Stability and Decline Over Time. Behind lifespan questions about differential change, there are many issues regarding not only the statistical reliability of change, but also the functional significance. Does change reflect a qualitative difference in status or at least a noticeable differences in performance, or is it simply a reflection of a potential to decline further? One way to address these issues is to consider the amount of variance explained in the present study. The majority of variability was accounted for by between-person variation, but there also was a sizeable amount of within-person variation that is indicative of (differences in) change over time. For example, 68% of the variance in social integration over time was due to between-person variance and 32% was attributable to within-person variance (see Appendix C for Section C.2.1.2). In addition, examining the effects of subgroup membership status in accounting for these differences revealed striking results. Subgroup membership accounted for substantive amounts of variability in baseline status (between 43% and 70% in the different domains of psychological functioning) as well as in change over time (23% – 45%). If one were to translate Cohen's (1977) classification of effect sizes from the ANOVA to Multilevel Models, the effects of the subgroup in accounting for heterogeneity in change over time were in the moderate to strong range of effect sizes.

Another way to evaluate the functional significance of differential stability and decline is to consider the actual amount of decline and its relation to previous findings. Subgroup decline over a period of six years on some of the profile-defining measures can be considered substantive because it amounted to half a standard deviation on measures such as perceptual speed, extraversion, and emotional loneliness. Previous 6-year longitudinal analyses from BASE carried out at the sample level reported smaller decline. For example, T. Singer and colleagues (2003) reported that linear decline for perceptual speed amounted to 0.32 *SD* units. The present study can be used to qualify these results in that the systemic-wholistic approach can be used to decompose the overall change trajectory for a given sample into several distinct developmental patterns over time as represented by subgroup trajectories. The sample trajectory of change on perceptual speed roughly represented change for the Disparate-Profile Subgroup, but both other subgroups were not found to show statistically significant decline on perceptual speed.

At a qualitative, overall functional level, decline in the present study occurred at high levels. There was no evidence for discontinuous, threshold-like developmental trajectories (Birren, 1959; Lövdèn, Bergman et al., submitted). It is unlikely that psychological decline in the three subgroups directly translated into serious and functionally relevant limitations. The change patterns for the three subgroups can be evaluated as representing more or less successful aging. The Overall-Positive Profile Subgroup showed considerable decline over time on measures of self-related functioning and social integration, but at the last measurement occasion their profile of functioning was still well above that of the other subgroups and also higher than the mean of the total cross-sectional BASE sample, which can be used as a reference standard. The Average-Profile Subgroup showed broad-band stability over time that can be qualified as robust aging. Macro-structural disadvantages for the group did not translate into higher relative risks for functional decline. This is especially interesting because subgroup members had ‘enough room’ for change because they were not at one of the extreme ends of the functional spectrum. If data were available on strategies of adaptation and compensation, for example, it would have been possible to examine what kind of strategies might have helped them to overcome the lifelong structural barriers and whether these were the same strategies that protected against functional decline in old age (P. B. Baltes & Baltes, 1990; Brandtstädter & Greve, 1994; Dixon & Bäckman, 1995; Heckhausen & Schulz, 1995). Participants from the Disparate-Profile Subgroup declined at a high functional level on cognitive abilities and managed to preserve their baseline functioning over time in the other

domains, which was especially pertinent to them because functional levels were low. Hence, subgroup members were also aging robustly.

Taken together, decline at elevated functional levels (though being substantive) and preserved stability over time suggest that the groups were more or less aging successfully and robustly over time (Garfein & Herzog, 1995; Manton et al., 1997). This interpretation is also corroborated by the survival benefits that members of the Overall-Positive Profile Subgroup showed despite their functional decline. At the same time, the present study also revealed initial evidence from a positively selected sample of individuals in old age that systemic-wholistic decline may have severe functional consequences: A small group of BASE participants showed pronounced decline across various domains of psychological functioning and, related to this, were vulnerable to subgroup transition, which in turn was accompanied by greater mortality hazards.

Systemic Patterns of Stability and Decline Over Time. To better understand psychological functioning in old age and its vulnerability to decline, a systemic-wholistic approach was chosen that allows to consider the systemic interplay of the different domains involved in the total functioning of the individual. To date, there is a relative dearth of empirical research from a systemic-wholistic perspective on how individuals maintain their functioning over time (see Section 1.3.4). The present study revealed evidence for different subgroup patterns of change, which indicate that particular configurations of psychological functioning were differentially vulnerable to decline over time. Among the issues to be addressed in the following is to ask to what extent change in the different domains was intertwined. For example, the operation of different sets of factors can be expected to bring about relative stability in one domain and decline in another domain as well as subgroup differences therein. This line of reasoning is illustrated using the patterns of change found among members of the Overall-Positive Profile Subgroup and the Disparate-Profile Subgroup.

First, functional decline in social integration among members of the Overall-Positive Profile Subgroup may represent decline at the upper functional level that is very difficult to circumvent in old age. Throughout most periods of life, collecting a social network (convoy) represents a more or less intentional and self-initiated process over which people exert relative control (Kahn & Antonucci, 1980). In old age, however, the picture changes because of the increasing incompleteness of the overall life course architecture (P. B. Baltes, 1997). Due to an increasing likelihood of social losses and functional limitations, individuals may have

less control over one's social network. Of course, it is still possible to exert active control, for example, by including new persons into one's social network who substitute those who died, but this may become increasingly difficult. It seems reasonable to assume that probability estimates for an 80-year old to replace a deceased close person with a new close other are substantively lower compared to a 70-year old, which may then result in relatively more feelings of loneliness (Johnson & Troll, 1992). Even if one assumes that older persons still actively shape the composition of their personal networks (Lang, 2001), a relative shift in social orientation from agency to belongingness with increasing age (or better: lifetime perspective and subjective nearness to death; Carstensen, Isaacowitz, & Charles, 1999; Lang & Carstensen, 2002) would suggest a relative shrinkage in overall social integration.

Maintenance of cognitive functioning over time can be interpreted in a selective maintenance framework (P. B. Baltes & Baltes, 1990; Brandtstädter & Wentura, 1995; Salthouse, 1995): Cognitive stability may have buffered against even stronger decline in the domains of personality and self-related functioning, and social integration. In this regard, one may also speculate about the functional role cognitive abilities play in the overall configuration of the psychological profile. Previous results from BASE, for example, suggested that high levels of cognitive functioning were not only associated with positive affect, but also showed associations with negative affect after controls were introduced for demographics, health, and personality variables (Isaacowitz & Smith, 2003). One interpretation of the link was that cognitive functioning can, of course, be regarded a general purpose mechanism for adaptation (P. B. Baltes et al., 1998), but may also have negative consequences. For example, preserved intellectual functioning relates to more engagement with life, which may cause both satisfaction and risk for dissatisfaction with life (e.g., disappointment, consciousness about age-related changes). Translated into the context of the present study, it would be possible to argue that a positive manifold between the constructs, which is known from variable-oriented research, may not directly translate into person-oriented research. It might well be that a group of individuals exists that is cognitively fit and more active in life. At the same time, these people have to deal with adverse personal and life circumstances such as loss of friends and close others.

Second, the Disparate-Profile Subgroup represented the focus group in the present study to examine notions about qualitative transitions in old age (e.g., Birren, 1959) suggesting that subgroups whose members were at the lower end of the functioning/desirability spectrum were relatively more vulnerable to decline over time. Consistent with the expecta-

tion, subgroup members showed relatively stronger decline on cognitive measures than both other subgroups. Cognitive decline was not only found on a central marker of fluid intelligence (perceptual speed), but also on a crucial indicator of crystallized intelligence (knowledge). Keeping in mind that members were relatively older, the results are also in line with lifespan scripts about the growing incompleteness of the life course architecture: Biological factors put increasingly severe constraints on intellectual functioning with advancing age (P. B. Baltes et al., 1998; see also Colsher & Wallace, 1991; Giambra et al., 1995; Schaie, 1996). As a consequence, age gradients for crystallized abilities turn negative after age 80 or so (directionality dedifferentiation) and these crystallized abilities are increasingly governed by fluid abilities ('mechanization' of crystallized abilities; Ghisletta & Lindenberger, 2003; Salthouse, 1996). It is also possible to argue that the psychological profile at baseline did not reflect a constellation that can be expected to promote the development and practice of intellectual abilities. Social participation, for example, has been found to act as a buffer against cognitive decline (Lövdèn, Ghisletta, & Lindenberger, submitted; MacKinnon, Christensen, Hofer, Korten, & Jorm, 2003). Subgroup members lacked this and other central resources for maintaining cognitive functioning (e.g., sense of control: Blatt-Eisengart & Lachman, 2004; Rodin, Timko, & Harris, 1985).

In contrast to the prediction, the Disparate-Profile Subgroup maintained their low functional levels on measures of self and personality, and social integration rather than showing additional decline. In his early writings, Birren (1959) acknowledged that "*the organism is a loose confederacy of many largely autonomous subsystems*" (p. 35). He suggested that the different subsystems become less autonomous only if critically low thresholds of functioning in a single vital domain are surpassed. In this case, functional constraints spread out across different domains and ultimately disturb them. This proposal is also consistent with lifespan scripts about the incomplete architecture of human ontogeny.

In the present study, the positively selected longitudinal BASE sample may have been functioning too well to have reached some kind of lower functional limit. For that reason, it was difficult to thoroughly examine the above notions about qualitative transitions in advanced old age. It was possible to demonstrate that differential sample attrition in BASE largely restricted the type and amount of change that could be observed over time: Participants who were not available for a third round of repeated assessments showed stronger decline as compared to those who took part three times. It seems reasonable to conclude that participants who maintained their low levels of functioning were more likely to continue

participation in BASE, whereas those who showed additional decline from relatively low functional levels were more likely to drop out of BASE either because of mortality or incapacity.

5. 1. 2. 3 *The Role of Cross-Disciplinary Factors for Profile Stability and Change*

To explore potential mechanisms underlying differential development in old age, a set of cross-disciplinary factors including age, gender, biological and life-history factors were examined as predictors of subgroup change over time. These measures were selected to broadly represent lifespan contexts of development and to indicate their evolutionary and ontogenetic nature (see Section 1.2.3). Very little evidence was found to indicate that these factors played a major role in determining (differential) change in the 6-year longitudinal BASE sample.

Lifespan scripts about the late-life consequence of the overall architecture of the lifespan (P. B. Baltes et al., 1998) and empirical evidence (Crimmins et al., 1996; Jorm et al., 1998; Smith & Baltes, 1997) suggest that the partial and domain-specific losses in the Third Age turn into a picture of generalized decline in the Fourth Age. In the present study, chronological age was used as an indicator for a possible transition between the Third Age and the Fourth Age. If age evinced predictive effects for differential change, it might have been seen as support for proposals that there is something like a transition between two phases of old age. At the subgroup level, the Disparate-Profile Subgroup represented the focus group because members were older. Their cognitive decline trajectories provided the only empirical instantiation that was in line with the expectation that advanced age was associated with pronounced subgroup decline over time.

Profile characteristics as well as the change pattern for members of the Disparate-Profile Subgroup reflected proposals about an increasingly negative gain–loss dynamic in the Fourth Age: Right from study inception, members in this subgroup had already low functional levels on psychological measures of personality and self-related functioning, and social integration. Over time, these participants showed substantive decline in the only psychological domain in which they were functioning well at baseline. Independent of whether low functional levels in the non-cognitive domains were present throughout their lives or whether they represent the outcome of decline in old age, having this specific psychological profile in the Fourth Age can be considered to represent a testing-the-limits situation for psychological

resilience (Smith & Baltes, 1997). Because of decreased plasticity, it is increasingly difficult to maintain relatively high levels of functioning, even in select domains.

The other change trajectories for the three profile subgroups were not in line with the age-prediction. Likewise, expectations about the predictive strength of gender and physical-functioning factors for maintenance or decline of psychological functioning also received very little empirical support in the context of the present study. The general positive selection of the 6-year longitudinal BASE sample may have made it very difficult to profoundly examine lifespan proposals that a different constellation of factors underlies differential development at the end of life than in earlier life phases (P. B. Baltes et al., 1998). In terms of age, proponents of considering different life phases in old age have acknowledged the large heterogeneity in the timing of age-associated changes by heuristically using age 85 to separate membership in either phase (e.g., Suzman, Manton et al., 1992). In contrast, the longitudinal BASE sample primarily included participants in their late seventies and early eighties, and more or less completely lacked individuals in their late eighties and older. Thus, there may have been too few persons to produce statistically significant age-associated differences in subgroup change over time. Consistent with this post-hoc interpretation, there were indications at the sample level ($n = 132$) that oldest-old BASE participants showed stronger decline over six years on the overall measure of functioning/desirability than young-old participants.

In terms of physical functioning, the 6-year longitudinal sample may have simply been functioning too well to have faced physical restrictions that in turn are associated with decline in other areas of functioning. The three subgroups were well above the mean of the total cross-sectional BASE sample on all physical-functioning measures and the only exception were greater health constraints in the Disparate-Profile Subgroup (see Section 4.1.4 for Figure 10). Caution, however, is necessary before interpreting the cognitive decline among subgroup members in the context of health restrictions and associated behaviors such as the use of medications (Anstey, Stankov, & Lord, 1993; Hertzog, Schaie, & Gribbin, 1978; Verhaeghen et al., 2003). In the context of the present study, health status for the Disparate-Profile Subgroup was not noticeably impaired because it still was at the average level with regard to the distribution of the total cross-sectional BASE sample. In addition, measurement properties are not readily comparable to other studies. Health was operationally defined as an overall measure (i.e., number) of medically-diagnosed moderate to severe illnesses and thus did not refer to specific sets of health impairments (e.g., cardio-vascular diseases vs. diseases of the muscular-skeletal system) and also excluded mild forms. Follow-up analyses indicated

that it was an accumulation of diseases rather than a single set of illnesses that distinguished among the subgroups at baseline assessment. Over time, change appeared to be associated with the same sets of factors across all subgroups, particularly if one acknowledges that each of the physical-functioning constructs declined, but not differentially among the groups.⁷

To summarize the section on differential development in old age and its underlying mechanism: The present dissertation study yielded substantive evidence to indicate that subgroups of individuals who share communalities and differences in psychological functioning at one point in time are relatively persistent over time. These subgroups also showed distinct patterns of change on the profile-defining measures. Taken together, findings highlight that there were systemic differences in the make-up of the subgroups at baseline and these differences had vital consequences for subsequent functioning and development over the six years of observation. The majority of subgroup members stayed together over time and the overall shape of their functional profiles remained stable, but at the same time, they decline on some of the single measures that constituted the profile. This reveals the systemic interplay among the different domains involved in the overall functioning and development of an individual (Magnusson, 1995). Due to the positive selection of the 6-year longitudinal sample, it was difficult to thoroughly examine questions about potential mechanisms underlying differential development in old age. The ensuing section discusses how profile information about psychological functioning in old age is linked to outcomes of successful aging.

5. 1. 3 Outcomes of Heterogeneity and Differential Development Over Time

To examine the long-term consequences of similarities and differences in profiles of functioning and change over time therein, two outcomes selected from the successful aging literature were examined (P. B. Baltes & Baltes, 1990; Rowe & Kahn, 1997; Ryff & Singer, 1998). Substantive evidence was found for the predictive strength of a systemic-wholistic approach for subjective well-being and 4-year survival: Subgroups with more functional/desirable psychological profiles at baseline assessment reported higher well-being six years later and also lived longer after the end of the study period than did the less desirable profile subgroups. Both effects were unique and robust in that they remained statistically

⁷ It is also unlikely that participants with psychiatric disorders such as dementia or mild cognitive impairment (for review, see DeCarli, 2003; Petersen et al., 1999) account for differential change. To begin with, base rates for cases with dementia were very low ($n = 3$) and results were the same when these participants were excluded. In addition, decline occurred at high levels of functioning, which are unlikely to be attainable by persons with some manifest form of cognitive impairment. Even if this were the case, one would expect selective memory drop-out with relative stability among other cognitive domains rather than the pattern found (i.e., decline on speed and knowledge and relative stability in memory).

significant after co-varying out the effects of other cross-disciplinary factors in old age including age, gender, life-history factors, dementia, multimorbidity, and sensory functioning, which represent past and current contexts of differential development in old age.

5. 1. 3. 1 *Well-Being*

Subjective well-being is a ubiquitous indicator of successful aging in lifespan research (Aspinwall & Staudinger, 2003; P. B. Baltes & Baltes, 1990; Kahneman, Diener, & Schwarz, 1999). The current study provides evidence from a systemic-wholistic perspective that subjective well-being can be used as a successful aging indicator that is susceptible to and indicative of systemic differences in psychological functioning. The finding gains in significance if one acknowledges that subgroups that were defined by different profiles of psychological functioning also were differentiated by a key subjective as well as an objective outcome. The current study adds to previous research by examining the predictive strength of information that is based on psychological profiles rather than single constructs.

At baseline assessment, differences in well-being between the three subgroups amounted to somewhat less than a standard deviation between the Overall-Positive Profile Subgroup and the Disparate-Profile Subgroup (effect size_{SD} = 0.81) and about half a standard deviation between the Overall-Positive Profile Subgroup and the Average-Profile Subgroup (effect size_{SD} = 0.45). Over time, these differences remained stable and group membership at baseline assessment explained 11% of the variance in well-being six years later.

Two aspects highlight that it was not trivial to having demonstrated that psychological profile subgroups differed from one another in well-being. First of all, it has to be acknowledged that there was no overlap in the definition of the subgroups and the psychological criterion variable chosen. Defining the groups did explicitly *not* involve measures that refer to mood or aspects of satisfaction with one's life in general so that group differences in well-being cannot be accounted for by measurement confounds. Second, there is large body of research to indicate a well-being paradox: Older people maintain well-being and satisfaction with life in the face of increased risks for social losses and declines in physical health and functioning (for review, see Diener et al., 1999). Despite constraints in objective life quality, the power of self-related resilience allows older people to maintain a sense of well-being. This is possible, for example, through processes of re-framing or accommodation that involve changes in expectations and reference standards (J. Heckhausen & Schulz, 1995). A large body of research has indicated that such motivational systems and self-protective processes

operate quite effectively in old age (e.g., Brandtstädter & Greve, 1994; Rott, 1999). Given this, it was an open question whether or not psychological profile differences also show up in well-being. The expectation was that subgroup differences were present, but clearly weaker than those for non-psychological factors. The actual magnitude of group differences in well-being was thus particularly striking.

The present study provides convergent evidence to previous qualifications of the well-being paradox, though from a different perspective, and extends these findings in several major ways. Recent evidence from BASE reported that physical illnesses was the only factor that explained considerable individual difference variance in well-being (Kunzmann et al., 2000).⁸ To begin with, despite the fact that health restrictions were found to characterize the Disparate-Profile Subgroup, these health limitations did not account for well-being differences between the subgroups. In addition, Kunzmann and colleagues (2000) qualified the stability-despite-loss paradox of well-being by using an *emotion*-based measure of well-being. In the present study, instead, well-being was measured by the PGCMS (Lawton, 1975). This measure contains subscales about non-agitation, satisfaction with life, and satisfaction with aging. Apart from the arousal component of agitation, this measure thus primarily assessed *cognitive* aspects of subjective well-being (i.e., evaluation of one's life and aging). Finally, the systemic-wholistic approach provided evidence for the claim that the so-called well-being paradox may not uniformly exist for all people in a given sample of older individuals.

5. 1. 3. 2 *Survival*

Objective indicators of heterogeneity and differential development in old age such as survival offer more substantial evidence for the validity of the method and the theory. One may argue that positive links between self-report measures (e.g., personality, well-being) and survival are artifacts of methodology. Such a concern cannot be made in relation to physical functioning or survival data.

Four years after last assessment, 50% of both the Average-Profile Subgroup and the Disparate-Profile Subgroup were dead, whereas the respective ratio was 32% in the Overall-Positive Profile Subgroup. Cox proportional hazards regression models revealed that the

⁸ The authors reported that positive affect (negative correlation) and negative affect (no significant correlation) were differentially related to age and functional health constraints. A potential mechanism underlying associations between health constraints and well-being might be that physical illnesses restrict an individual's involvement with the external world including social participation, which in turn may have detrimental effects on aspects of well-being (Carstensen, 1993; Ryff & Singer, 1998; Smith, Borchelt, Maier, & Jopp, 2002).

hazards of dying for the Overall-Positive Profile Subgroup were about half of those for the other two less well-functioning subgroups combined. Mortality hazards diverged relatively early (by approximately two years) over the four-year period and remained more or less constant afterwards. Because less than fifty percent from the Overall-Positive Profile Subgroup have died over the four-year period, one has to await additional mortality data to thoroughly determine whether or not the group divergence in mortality hazards further accumulates over time (J. Singer & Willett, 2003). Combining the Average-Profile Subgroup and the Disparate-Profile Subgroup resulted in more stable estimates (due to increased statistical power), but survival differences were also evident when comparing the subgroups separately. Using percent-wise effect size estimates rather than weeks or months was one way to deal with the problem that the latter statistics tend to be unstable if the distribution of censored and uncensored cases (i.e., dead vs. alive) is skewed.⁹

Sceptics might argue that the finding about subgroup predictors of mortality was simply due to the strong individual variables underlying subgroup identification. Cognitive status, for example, is recognized as one psychological variable that predicts mortality in late life (Bosworth, Schaie, & Willis, 1999; Small & Bäckman, 1997; White & Cunningham, 1988). Such findings from function-oriented research may suggest that cognitive decline found in the Disparate-Profile Subgroup may be the driving force underlying the predictive effect for subgroup membership status for subsequent mortality. For a number of reasons, however, this interpretation has to be cautioned. To begin with, mortality hazards for members of the Disparate-Profile Subgroup were not different from those for members of the Average-Profile Subgroup who maintained their levels of cognitive functioning over the study period. Furthermore, cognitive decline for the Disparate-Profile Subgroup occurred at relatively high functional levels suggesting that cognitive deterioration observed among these 6-year longitudinal BASE participants does not represent terminal decline processes in their classical sense (Kleemeier, 1962; Riegel & Riegel, 1972). It was not possible to disentangle the mortality differences and their underlying mechanisms in the two less well-functioning groups, which may or may not differ from one another. The very fact that the Average-Profile Subgroup and the Disparate-Profile Subgroup were found to have similar mortality hazards over a period of four years is in line with lifespan scripts about the gain loss dynamic: The same overall outcome of a net sum of gains and losses can be brought about by very different

⁹ For discussion of the effects that the duration of follow-up may have in mortality analyses, see Meinow, Kareholt, Parker, and Thorslund (2004). In essence, the authors reported that rather unstable predictors (e.g., health) have stronger effects in short-term predictions (e.g., one or two years of follow-up), whereas the effect sizes of rather stable predictors (e.g., social contacts) were less affected by the length of the follow-up period.

constellations and constituting profiles of functioning. Overall, it seems as if it was the conjoint contribution of many small effects of the single profile-constituting dimensions that lie behind the predictive strength of the profile approach. High levels of functioning in a number of different psychological domains seems to represent a key factor for the survival differences found.

Subgroup status predicting survival over time was found to be a robust phenomenon. Survival differences between subgroups identified on the basis of psychological profile information were independent of a number of cross-disciplinary factors that represent past and current contexts of development (P. B. Baltes et al., 1998) and that have also been found to link to mortality (e.g., Adler & Snibbe, 2003). One may have argued that relative health impairments in the Disparate-Profile Subgroup and the SES constraints in the Average-Profile Subgroup were linked to elevated mortality hazards, but these factors alone cannot explain these differences. Although sensory functioning and multimorbidity also predicted survival at the zero-order level, subgroup status was the only factor that was significantly associated with survival once all other factors were taken into account. A note should be added on the effect of chronological age. After additional controls were introduced for age, the subgroup effect slightly surpassed the .05 significance level, but the trend was preserved numerically. In addition, the groups also showed statistically significant mortality differences when examined separately, and there were no age differences between the Average-Profile Subgroup and the Disparate-Profile Subgroup. Both aspects suggest that differences in chronological age alone cannot explain survival differences between profile subgroups.

Evidence of differences in mortality hazards between profile subgroups can also be embedded into previous person-oriented research. The Overall-Positive Profile Subgroup had a similar survival advantage as did Subgroup A and Subgroup C identified in the Gothenburg study (Maxson et al., 1996; see Section 1.3.4 for Table 1). In the same vein, the Disparate-Profile Subgroup resembled the Gothenburg Subgroup D in their higher mortality rates. Andrews et al. (2002) also reported from the Australian Longitudinal Study on Aging that groups of participants who were classified as aging successfully across measures of physical and cognitive abilities were living longer as compared to groups that aged less successfully. Similarly, Smith (2003b) reported that the subgroups identified in the total cross-sectional BASE sample (Smith & Baltes, 1997) also were predictive of mortality. The odds of dying increased significantly by a factor of 2.3 with membership in a less desirable profile group, independent of age, gender, physical health, and functional capacity. The current work adds

to these previous reports by having demonstrated that profile differences also have unique predictive effects when (a) the sample is positively select in a number of different functional domains and (b) profile-defining constructs examined separately do have no or minor predictive effects of survival.

5.2 Limitations of the Present Study

The Berlin Aging Study (P. B. Baltes & Mayer, 1999) was aimed at a comprehensive and in-depth investigation of individuals in old age by using a broadly-based multidisciplinary measurement approach. Embedded in the context of the Berlin Aging Study, the present dissertation thus was in the privileged situation to realize three major research design issues that can be considered essential to thoroughly examine questions about heterogeneity and differential development in old age (see Section 1.2.3). Data on multiple domains of functioning including psychological and cross-disciplinary measures were available from an age-heterogeneous sample of participants in old as well as advanced old age and these participants were assessed three times over a period of six years. By using these data, a systemic-wholistic approach was adopted to examine research questions derived from lifespan scripts about the contexts of developmental change and the evolutionary and ontogenetic foundations of change (P. B. Baltes et al., 1998).

However, it is also important to acknowledge potential limitations of the study that constrain the conclusions to be drawn. Three major aspects require special consideration: (1) The difficulties involved in examining questions derived from lifespan scripts about development, (2) constraints imposed by study design and resulting sample characteristics, and (3) concerns about the methods, profile-defining measures, and analysis strategies chosen.

5.2.1 Difficulties in Empirical Examinations of Lifespan Scripts About Development

One goal of the dissertation was to use lifespan scripts about macro-contextual systems of influence on development and the evolutionary and ontogenetic nature of these influences (P. B. Baltes et al., 1998) to derive and operationalize research questions about heterogeneity and differential development in old age. Heterogeneity was operationally defined at a systemic-wholistic level as subgroups, which manifest different profiles of psychological functioning. To define the subgroups, a bottom-up strategy of person classification was chosen by using cluster analysis. Further research is required to supplement such data-based ‘inductive’

categorization of individuals by more top-down strategies and by studies that explicitly opt for qualitative and idiographic research approaches rather than nomothetical approaches.

Differential development in old age was operationally defined as subgroup differences in stability and change over time in terms of both membership and profile-defining measures. This strategy again represents just one of many ways to examine the extent to which individuals differ from one another in how they develop over time. Future research may use a different time metric to explore the convergence of age-related and death-related processes (Busse, 1969; Kleemeier, 1962; Riegel & Riegel, 1972; Small & Bäckman, 1999).

In the context of the present study, there also were limitations to study lifespan scripts about the late-late consequences of the increasing incompleteness of the biocultural orchestration of the life course (P. B. Baltes, 1997). It was difficult to examine notions about separating different phases in old age (i.e., Third Age and Fourth Age) because sample attrition was particularly pronounced among oldest-old participants so that few individuals in the Fourth Age were left for repeated assessments. Having found evidence for an increasing importance of age-graded factors at the highest age ranges illustrates that, if anything, the present results underestimate these differences. Similarly, the positive selection of the longitudinal BASE sample made it difficult to thoroughly examine lifespan scripts about the increasing relative strength of biological factors over cultural factors in determining development in advanced old age (P. B. Baltes et al., 1998; Crimmins et al., 1996; Olshansky et al., 2001; Jorm et al., 1998; Kirkwood, 2002).

A general difficulty of large-scale longitudinal studies is to determine the role of cohort-graded factors and idiosyncratic factors in co-producing regularities and differences in development. To explore the relative importance of cohort differences in development, longitudinal studies involving multiple cohorts are in fact necessary (cohort-sequential designs; P. B. Baltes, 1968; Schaie, 1965) because otherwise, age-graded and history-graded factors are confounded. Participants in the 6-year longitudinal BASE sample were born between 1893 and 1922, which means that they have experienced many historical events. The oldest birth cohorts were around age 20 at the time of World War I and the youngest cohorts were born around this time. All participants experienced World War II, but did so at various points in their lives. Their educational and occupational opportunity structures as well as their health experiences and family lives were affected by these cohort-specific experiences (Dannefer, 2003; Mayer, Maas, et al., 1999; Riley, 1987; Smith & Gerstorf, in press). This suggests that the three profiles of psychological functioning and their developmental patterns over time

might be specific to some subgroups of individuals in this particular birth cohort that may or may not be found among later-born cohorts. For example, the relatively well-preserved functioning despite macro-structural constraints in the Average-Profile Subgroup can be interpreted in the context of cohort effects: Earlier-born cohorts have experienced relatively more hardships (e.g., lower education, lower wage rates, higher number of weekly hours at work) so that their perception and evaluation of life conditions is different from that of later-born cohorts (Idler, 1993).

It is also very difficult to examine the role of idiosyncratic factors in large-scale longitudinal samples, particularly when the analysis strategy obtained is a nomothetical one. Implementing the systemic-wholistic approach by pattern-oriented methods such as cluster analysis preserves the theoretical focus on the individual and may thus allow to identify those factors that affect development, but that do not correlate with age and historical time. Because communalities and differences between such factors can often be identified at a more aggregate level (see also Section 1.3.3), it seems possible to investigate idiosyncratic factors at a meso level. In a similar vein, specific age-graded and history-graded factors may also be acting at the meso-level in that they operate for one subgroup more strongly than for others. One potential future avenue in this regard is research on subgroups of individuals who share specific bodies of declarative and procedural knowledge such as expertise, which are suggested to result from idiosyncratic combinations of cognitive abilities, motivation, personality characteristics, experiences, and deliberate practice (Ericsson et al., 1993; Salthouse, 2003). This area of research appears to be particularly interesting from a perspective of heterogeneity and differential development because it has largely been demonstrated that this acquired knowledge allows individuals to postpone or attenuate the consequences of age-associated losses in the cognitive mechanics in this specific domain (Charness, in press).

5. 2. 2 Constraints Imposed by Study Design and Resulting Sample Characteristics

Characteristics of the study design and the resulting sample, of course, play a major role in whether or not researchers are sufficiently equipped to examine questions about differential stability and change over time in old age. The following sections discuss the study design of the present work, its implications for differential sample attrition and the characteristics of the remaining sample, and the consequences for embedding the results found into the existing literature.

From the analyses presented it becomes apparent that traditional longitudinal research designs provide only limited information to study differential development. To start with, changes observed in longitudinal data sets are noticeably shaped by study duration and length of time intervals between occasions. There is a shortage of lifespan psychological conceptions about the time frames during which developmental transitions can be observed (Birren & Cunningham, 1985; Smith, 1999). Such notions would be necessary to conceptually decide upon the time intervals between measurement occasions in large-scale longitudinal studies. In contrast, many traditional designs involve study duration and length of time intervals that are based on practical and economic aspects rather than conceptual arguments.

In the present study, study duration was six years in total with a 4-year and a 2-year interval between the waves, respectively. This study design, of course, provides potential limitations in examining change in different domains of functioning. To begin with, six years may have been *too short* to examine questions about change over time in constellations of psychological dimensions that may take a rather long time to change visibly such as those that involve personality traits. On the other hand, a wave interval of two years may have been *too long* to assess persons who suffer from functional breakdown such as terminal decline because these participants would have dropped out of the study either because they were already dead or they were no longer capable to do the testing. In this way, the same study interval of, let's say, 4 years can be considered too short to thoroughly examine change over time among individuals in their 70s, whereas it is too long for individuals in their 90s who are likely to die or to become incapable of doing the testing.

To better understand subgroup differences in psychological profiles and change over time, preliminary analyses were carried out to determine the effects of differential sample attrition in the 6-year longitudinal BASE sample. Investigating attrition effects from a systemic-wholistic perspective added to previous selectivity results from BASE (e.g., Lindenberger et al., 2002; T. Singer et al., 2003; Smith & Delius, 2003) and from other large-scale longitudinal studies (e.g., Cooney et al., 1988; Rabbitt et al., 2004; Siegler & Botwinick, 1979; Sliwinski & Buschke 1999; Zelinski & Burnight, 1997). Attrition effects of psychological factors can not only be found for measures of cognitive functioning, but also across multiple domains of psychological functioning including personality and self-related functioning, and social integration. Although chronological age was confounded with these differences, age alone could not completely account for the effects.

In addition, differential attrition effects were not restricted to the variable-level, but also generalize to the subgroup level: Members of desirable psychological profile subgroups from the total BASE sample were about four times more likely to be part of the longitudinal sample as compared to less desirable subgroups. As a consequence, the three subgroups identified in the longitudinal sample primarily reflected different variants of successful aging. In terms of mean levels of performance, the Overall-Positive Profile Subgroup included the most selected participants because their baseline status was between one half and three quarters of a standard deviation above the mean of the total cross-sectional BASE sample throughout the profile-defining domains. In terms of change over time, the patterning of subgroup differences suggests that change trajectories for the Disparate-Profile Subgroup were most strongly shaped by differential sample attrition, or, more precisely, lack thereof (see Section 4.2.2.2.1). The general argument already made earlier is that if these lower-functioning participants would had experienced the same amount of decline as did higher-functioning participants, they most likely would have dropped out of BASE, either because of mortality or incapacity. This finding is in line with evidence from function-oriented research on cognitive decline, which suggests that cross-sectional age gradients are steeper than longitudinal age gradients (Schaie, 1996; but see Sliwinski & Buschke, 1999; Zelinski & Burnight, 1997). It seems reasonable to conclude that applying a systemic-wholistic perspective to study the effects of differential sample attrition at different levels of analyses has revealed important and unique insights.

Findings of differential sample attrition have implications for generalizing research findings. In face of the special characteristics of the BASE design (i.e., local representativeness, stratification by age and gender, intensity of measurement), the pattern found cannot be generalized straightforwardly to other large-scale research with different study designs. To begin, the total BASE sample was locally representative (Lindenberger et al., 1999): Studies that have used other recruitment criteria likely cover a less wide range of psychological functioning, at least at baseline assessment. For example, the Seattle Longitudinal Study used membership in private health insurances to recruit their participants (Schaie, 1983) and can thus be expected to relatively lack less functioning/desirable subgroups (e.g., fewer individuals with low SES, cognitive impairment, etc.). The age and gender stratification of the total BASE sample also represents a special design feature: Samples reflecting age and gender ratios in the population likely contain fewer participants in close proximity to death. Thirdly, an especially important feature of BASE is the very intensive and time-consuming data col-

lection procedure (up to 26 sessions over six years): This contrasts to other large-scale longitudinal studies that involve more of a survey-type assessment battery and are thus less demanding.

These study design characteristics make BASE a very unique type of data set. One can expect, then, that (age-associated) selection and attrition effects observed in BASE were larger than in many other studies (Lindenberger et al., 1999; T. Singer et al., 2003) and thus do not directly generalize to these inquiries. Acknowledging that selectivity in BASE was certainly at the higher end of what is possible does by no means imply that non-random selection and attrition effects can be disregarded in other studies. The very fact that the present grouping of individuals was embedded into previous person-oriented research (see Section 5.1.1), although numerous differences exist in sample characteristics and the techniques used to group individuals together, can be interpreted to highlight that argument. Because of the relative scarcity of longitudinal work from a person-oriented perspective, it is largely an open question to what extent findings of subgroup differences in development over time in old age can be generalized.

5. 2. 3 Concerns about Methods, Profile-Defining Measures, and Analysis Strategies

These concerns relate to alternative methods that allow to specifically address some of the difficulties associated with cluster analysis, the selection of profile-defining measures, the domain-specific or domain-generalized character of functional differences and change over time, and the interplay between functional status and social desirability.

Alternative Methods to Implement a Bottom-Up Strategy of Person Classification. Cluster analysis represents just one method that can be used to classify individuals into subgroups. To address some of the difficulties associated with using cluster analysis, the results of additional person-oriented methods could have been evaluated for providing convergent evidence.¹⁰ For example, methods that index the goodness of fit between a given individual and the subgroups would have provided additional information about the integrity of the three subgroups identified. These analyses would have been informative because the grouping of individuals in BASE was consistent with ideas about fuzzy sets (see also Zetenyi, 1988): Because the subgroups cannot be expected to differ qualitatively from one another, the sub-

¹⁰ One exemplar control analysis that combines the consideration of profiles and change over time therein would be a time-reversed strategy that uses the profiles at the last measurement occasion and then proceeds backward in time (for details, see P. B. Baltes et al., 1972).

groups are not clearly separated from one other and it is thus not possible to unambiguously assign each individual to one of the groups. Most individuals can be assigned to the best-fitting group, but there is some uncertainty in assignment at the boundaries between subgroups (in addition to measurement characteristics of the group-defining constructs such as reliability). From this also follows that transiting from a given subgroup to a different subgroup at later measurement occasions is a continuous and smooth rather than a discontinuous process. Based on such fuzzy-set rationale, the Grade-of-Membership technique (GoM; Woodbury & Manton, 1982), for example, could have been applied to determine the extent to which an older individual and the subgroup he or she was assigned to matched together. In this regard, GoM computes statistics to estimate both the degree of membership in multiple groups and the distinctiveness of the groups identified (e.g., Kinoshian et al., 2000).

Due to a number of different reasons, it was not possible to apply the GoM technique in the present study. First, GoM requires categorical data to define the groups as opposed to the continuous measures used in the present cluster analyses. Second, GoM represents a method that is primarily used in epidemiological research and to operate robustly, large numbers of both sample size and group-defining constructs are usually involved. For example, Manton, Cornelius, and Woodbury (1995) applied GoM to define groups among 4,525 nursing home residents; the authors used 111 measures across different domains such as medical conditions, cognitive performance, and use of services. Most importantly, the mathematical algorithm used by GoM to identify the subgroups is reasonably different from that of cluster analysis. In cluster analysis, subgroups are detected by minimizing within-group and maximizing between-group differences so that subgroups can be described by the distance between each member and the average of all members on a given variable. In GoM, however, extreme behaviors are estimated at the far-functioning end of a given variable and other behaviors are described by their distance from these extremes. Despite these methodological differences, statistics indicating how well individuals and subgroup matched together would have been interesting.

Concerns About the Selection of Profile-Defining Measures. Smith and Baltes (1997) selected the profile-defining measures of cognitive functioning, personality and self-related functioning, and social integration to broadly represent central characteristics of psychological functioning in old age. Previous studies on differential development in old age from the systemic-wholistic perspective, as reviewed in Section 1.3.4 (see also Table A.1 in Appen-

dix A), have often used a subset of these measures. This assures across-study comparability at the domain level, but at the same time the selection of indicators within the domains may have limited the present study in determining differential development. It could be that other indicators would have been more sensitive to change so that a different patterning of subgroup differences in development over time would have resulted. Further indicators of cognitive functioning that were not used in this study are episodic memory or reasoning. Similarly, conscientiousness represents an additional personality indicator, and the size of the overall social network would be a further social integration indicator.

Functional Differences and Change Over Time: Domain-Specific and Domain-Generalized Perspectives. Another potential concern about the present study relates to the strategy that group differences were examined and discussed at the domain level rather than the dimension-specific level. Given the existence of large within-domain differences, this level of data aggregation may have been overly broad. For example, it has long been recognized that within-domain differences in cognitive aging trajectories between fluid intelligence and crystallized intelligence are substantial (e.g., Schaie, 1996). In the domain of personality and self-related functioning, even less structural coherence has been reported so that it would be difficult to argue for constructing a homogenous measure to describe a person's functioning in the different sub-domains of personality and self-functioning (Smith & Baltes, 1999). With these concerns in mind, domain-composite measures were used in the following way. All central analyses were carried out at the dimension-specific level (e.g., identification of subgroups, examination of differential subgroup change over time) to preserve the differentiated picture within each domain. Domain-composite measures were primarily used in the context of follow-up analyses and for communicative purposes. The patterning of subgroup differences in baseline functioning and particularly in subsequent change over time became especially visible at the level of the psychological domains.

A domain perspective is also consistent with recent attempts that call for a broader and more integrated perspective on psychological functioning and underlying processes. In personality research, for example, Hooker and McAdams (2003) proposed a six foci model, which attempts to integrate structures (traits, personal action constructs, and life stories) and processes (states, self-regulation, and self-narration). A stronger inclusion of the latter process constructs in future work may also contribute to furthering our understanding of the mechanisms underlying heterogeneity and differential development over time.

Interplay Between Functional Status and Social Desirability. A final set of concern relates to evaluating the subgroups along a dimension of functional status or (social) desirability. Problems that may arise from such evaluation include disagreement about the adequate way to evaluate performance levels and the functional significance of such evaluations (see also Aldwin, 1991).

To begin with, it is circular to predefine top, average, and bottom levels of psychological functioning because there are no explicit criteria available to judge the efficacy status of a given functional level. In the absence of absolute norms for what can be considered psychologically functional, many studies used arbitrary empirical criteria to define cut-off points (e.g., Smith & Baltes, 1997: above vs. below sample average). A more refined evaluation procedure, for example, is the concept of allostatic load,¹¹ which signifies the cumulative wear and tear across multiple physiological systems that follow from genetic predispositions and psychosocial adversity (McEwen & Stellar, 1993; Ryff & Singer, 1998). Owing to systems thinking, increased functional risks are conceptualized to result not only from large and clinically significant dysregulation in individual systems, but also from more modest dysregulation, if present in multiple systems (Karlmann, Singer, McEwen, Rowe, & Seeman, 2002).

Concerns also arise from evaluating thoughts, characteristics, and performances as generally functional or dysfunctional for adaptation rather than linking it to specific contexts. Characteristics evaluated as dysfunctional might be adaptive in particular contexts such as knowing that close others care for one self in times of need (e.g., external control beliefs: M. M. Baltes, 1996; Johnson & Barer, 1992). Another example comes from Bak and Brandtstädter (1998) who reported that two coping strategies widely suggested to reveal buffering effects (tenacity and flexibility of goal pursuit) were adaptive only if used separately, but not when being pronounced in combination. A related issue concerns the objection that psychological functioning/efficacy and social desirability may covary in many, but not in all instances. Keeping these concerns in mind, the Smith and Baltes study (1997) assigned valence to the profile-defining psychological dimensions as a heuristic tool to characterize the profile-subgroups. The objective was to base the higher functionality of (psychological) dimensions on a general consensus about what dimensions can be considered on average and in the long term functional or dysfunctional.

¹¹ Allostatic load is operationally defined as a composite index assessed across measures of cardiovascular activity, serum DHEA-S, 12-hour urinary cortisol, epinephrine and norepinephrine excretion.

In sum, this dissertation study had to deal with several difficulties and constraints in the examination of heterogeneity and differential development in old age. Despite differential sample attrition, evidence was found for sizeable heterogeneity. Despite constraints imposed by study design issues, evidence was found for differential development in old age. Of course, the interpretation of results is contingent upon methodological considerations, but if anything, then the findings revealed by this work underestimate the different constellations and combinations of functional profiles and their differential development over time. After reviewing limitations of the present study, the next session discusses in detail the unique insights gained from applying a systemic-wholistic approach to study aspects of heterogeneity and differential development in old age.

5.3 Unique Insights Gained From Combining the Lifespan Perspective with a Systemic-Wholistic Approach to Study Heterogeneity and Differential Development in Old Age

A chief objective of the present study was to utilize the systemic-wholistic approach to find answers to some of the key questions about heterogeneity and differential development in old age. The dissertation was embedded in lifespan scripts about developmental contextualism and co-constructivism (for overview, see P. B. Baltes et al., 1998), and successful versus less successful aging (P. B. Baltes & Baltes, 1990; Rowe & Kahn, 1997; Ryff & Singer, 1998). These scripts were used to formulate and test questions about profiles of psychological functioning in old age, enduring changes in these profiles over time as well as about underlying mechanisms and outcomes. The present study evinced substantive evidence that the systemic-wholistic perspective can be used as a tool to capture facets of heterogeneity and differential development in old age and thus complements variable-oriented approaches that are more function-, element-, and domain-specific.

Because of concerns about the methodology appropriate for implementing the systemic-wholistic approach (e.g., randomness of classification, short-term variability), the present dissertation study attempted to demonstrate the utility of the three subgroups identified by cluster analysis. To do so, a number of different criteria were established (Aldenderfer & Blashfield, 1984; Milligan & Copper, 1987). These criteria were organized around three objectives central to research on heterogeneity and differential development. To this end, the dissertation has gone beyond what is usually done in a single study from a systemic-wholistic perspective. A first major step was to categorize individuals based on empirical multivariate

assessments. The focus was on exploring whether subgroup structuring was possible in principle and whether heterogeneity can in part be attributed to differences between subgroups of individuals. In a next step, it was attempted to further refine and validate the subgroups. This involved, for example, longitudinal analysis of the degree of stability and change and analyses aimed at an understanding of the factors and processes that lead to such profiles of functioning and developmental changes therein. In a final step, additional correlates and consequences for future pathways of change were explored.

Identification and Description of the Range of Heterogeneity and Its Correlates. Methods to implement the systemic-wholistic approach consider similarities and differences among individuals without a priori specifying a certain structure underlying the functional profiles. It is thus possible to take into account linear as well as non-linear relationships among the profile-defining measures and so gain insights otherwise scarcely captured (Bergman, 1998).

In the context of the present study, subgroups with diverse profiles of functioning were observed although function-oriented research had suggested a positive manifold among the dimensions considered.¹² The pattern for members of the Disparate-Profile Subgroup represented a converse interaction of cognitive functioning and social integration rather than a positive correlation among the subgroup-constituting domains (e.g., Andrews et al., 2002; Lachman, 1986; Schaie, 1996). In a similar vein, members of the Average-Profile Subgroup were found to buffer substantive macro-structural barriers and to reach old age in a reasonably good condition across measures of physical and psychological functioning although these functional measures correlate positively with life-history status at the population level (Schaie, 1996).

In addition, the Average-Profile Subgroup and the Disparate-Profile Subgroup showed very similar scores of desirability on an overall measure of psychological functioning, but the constituting constellations of psychological factors were very much different from one another. This finding is in line with lifespan scripts about the biological-environmental co-construction of the life course and the influence of age-graded, history-graded, and non-

¹² The three subgroups also represent more than a mere variance split-up on an overall-functioning index: Factor Analysis revealed that the measures did not load on a single underlying factor, but at minimum made up two factors. One factor basically represented cognitive aspects, while the other factor primarily reflected measures of social integration. These results are essentially in line with those reported by M. M. Baltes and Lang (1997) who applied an exploratory factor analysis to data from the total BASE sample and identified a sensorimotor-cognitive resource factor and a social-personality resource factor (see also Lang, Rieckmann, & Baltes, 2002).

normative factors, which co-produce communalities and differences in patterns of human development across the life course (for overview, see P. B. Baltes et al., 1998). Heterogeneity prevails in a sample of individuals in old age who in a number of different ways represent a positive selection of their birth cohort. The finding can also be taken to highlight lifespan scripts about the gain-loss dynamic (P. B. Baltes, 1987; Dixon & Bäckman, 1995) suggesting that the identical overall sum total of gains and losses can be the result of various constellations of gains and losses across different domains of (psychological) functioning. Age-graded factors may have had a strong impact in the Disparate-Profile Subgroup as evinced by larger health constraints, whereas history-graded factors may have largely been involved in the Average-Profile Subgroup.

In contrast to relatively small negative age differences at the individual-variable level that were reported from the total BASE sample (with the exception of cognitive functioning: Lindenberger & Baltes, 1997), the systemic-wholistic perspective evinced pronounced differences between BASE participants in the Third Age and those in the Fourth Age. Such broad and systemic approach thus provided additional support for lifespan scripts about late-life consequences of the increasing incompleteness of the biocultural orchestration of the life course and the augmented importance of age-graded factors in advanced old age. In the Fourth Age, systems that contribute to a positive ratio of gains over losses seem to break down functionally (Birren, 1988; Smith, 2003a; Uttal & Perlmutter, 1989). As a consequence, the oldest-old population experiences lower quality of life and a new developmental agenda arises in that the adaptation to outcomes of age-related losses is severely challenged. The fact that convergent evidence to previous reports was found (Crimmins et al., 1996; Jorm et al., 1998; Smith & Baltes, 1997) although heterogeneity was largely reduced in the 6-year longitudinal BASE sample highlights the utility of the approach taken.

Differential Development and Its Underlying Mechanisms. A systemic-wholistic approach may complement function-oriented research because the focus is not on identifying a common developmental trajectory and to describe individual and subgroup differences as deviations from that overall trajectory. Instead, the approach attempts to demonstrate that a given overall trajectory may be decomposed into several distinct developmental patterns (Bergman & Magnusson, 1997).

Acknowledging the inconsistent literature about uniform or differential decline trajectories in old age (e.g., cognitive functioning: Hultsch et al., 1999 vs. Schooler & Mulatu, 2001),

the very fact that differential development over time between the subgroups was observed in this dissertation study and demonstrated to be reliable and robust as well as the size of the effect are all remarkable. Evidence that a window on change in old age over a period of six years is sufficient to observe heterogeneity in developmental trajectories from a profile perspective, but less so from a single-variable perspective (e.g., T. Singer et al., 2003) underscores that unique insights can be gained from adopting a systemic-wholistic perspective. The finding also challenges uniformity-of-nature assumptions. For example, many cognitive aging researchers have, at least implicitly, accepted the assumption that cognitive aging is invariant across individuals (see also Lövdèn, Bergman et al., submitted). In contrast, the current study demonstrated that individuals who share communalities in their functional profiles at a specific point in time tend to show similar developmental trajectories over time, which in turn deviate from those of individuals who were characterized by a different functional profile.¹³

The proximity of the systemic-wholistic approach to index overall functioning may underlie its predictive strength for differential development in old age. Many studies on the issue have used macro-structural indices such as life-history factors or gender that refer, at a very general level, to the cumulative effects of past and current developmental contexts. Studies using these indices have often failed to find evidence for differential patterns of change (e.g., Lövdèn et al., 2004; for review, see Anstey & Christensen, 2000). Among other reasons, this may come about because these classification systems are too broad so that intra-group diversity overshadows inter-group differences. It seems as if more proximal categories such as psychological profile characteristics may thus be better suited to capturing heterogeneity in developmental processes in old age (see also Maddox & Clark, 1992). This interpretation is also in line with evidence from function-oriented research suggesting that individual differences in more proximal measures of social participation revealed stronger associations with age-related changes than did more distal socio-biographical measures (e.g., M. M. Baltes, Maas, Wilms, Borchelt, & Little, 1999).

One further unique feature of the present study is to have demonstrated that subgroups of individuals who were grouped together at one point in time also were, to a considerable degree, grouped together several years later. This relative continuity and temporal integrity of the subgroups underlines their credibility. In addition, BASE participants whose subgroup

¹³ More in-depth studies are, of course, required to specifically examine the exact shape of these developmental trajectories. Hence, it is an open question whether aging processes in a given functional domain can still be described by a single trajectory and individuals and subgroups only differ in the timing of decline onset.

membership was not stable over time were exploited as representing one additional aspect of differential development in old age. Having identified a small portion of study participants who showed pronounced and systemic decline across multiple domains of psychological functioning, which was accompanied by moving to a different subgroup and by elevated risks of dying was only possible through opting for a systemic-wholistic approach.

Outcomes of Heterogeneity and Differential Development Over Time. Notions that profile differences also represent potential sources for continued differentiation in the future (Smith, 2003a; Thelen, 1989) were confirmed in the present study by linking subgroup membership status at baseline to successful aging outcomes over time, subjective well-being and 4-year survival. The aim was not to carry out a direct methodological comparison between a function-oriented approach and a systemic-wholistic approach to demonstrate that the consideration of profile information might result in added information and predictive power. Such comparisons often imply an either-or-perspective on the issue and to be fair a number of methodological adjustments are required (e.g., number of predictors, see Asendorpf, 2003).¹⁴

If one were to take the route of comparing the approaches with one another, the present study would offer striking evidence that a systemic-wholistic approach revealed insights otherwise not gained. Acknowledging that all three profile-defining domains of psychological functioning have been found to be linked with well-being (cognition: Isaacowitz & Smith, 2003; personality and self-related functioning: Diener & Lucas, 1999; social integration: DeNeve & Cooper, 1998; Pinquart & Sorensen, 2000), follow-up analyses compared the predictive effects for these measures to those of the systemic-wholistic approach. Although some of the profile-defining measures were predictive of well-being at the zero-order level (e.g., perceptual speed), these effects usually vanished when controlling for the covariates, and subgroup membership remained to be a unique predictor in these analyses. As is to be expected, neuroticism was the only profile-defining measure for which a robust predictive effect was found, but subgroup membership also remained a unique predictor of well-being in these analyses. Overall, subgroup membership entails information for the prediction of well-

¹⁴ Asendorpf (2003) directly compared the predictive abilities of the Big-Five personality traits (Costa & McCrae, 1985) against that of personality (sub)types and found incremental validity of profile information only in very few cases. Asendorpf (2003) and others concluded that subgroups (or ‘types’ in personality terms) “do not refer to distinct, homogeneous classes of persons” (Costa et al., 2002, p. S73) and have “little utility for predictions from personality” (Asendorpf, 2003, p.344). He recommended to restrict the use of such approaches to descriptive purposes such as communication to the general public rather than predictive purposes.

being over time that was not fully captured by a function- or variable-oriented research approach.

In contrast to analyses carried out with the total BASE sample (Maier & Smith, 1999: 11 out of 17 indicators of psychological functioning were identified as significant predictors of mortality hazards at the zero-order level), the only single psychological factor found to be associated with survival in the 6-year longitudinal BASE sample was memory. This evidence once again underscores the positive selection of the longitudinal BASE sample. It is particularly impressive that subgroup membership was found to predict survival although 10 out of 11 variables that defined the subgroups were not. This subgroup finding exemplifies that considering patterns or profiles across various domains of psychological functioning might give unique insights into questions about heterogeneity and differential development and its long-term consequences. Differences in mortality hazards may have been subtle on the single dimensions, but they may accumulate and become functionally relevant when examined conjointly. The functional relevance of the effect can be seen in the fact that the probability of death was doubled for the pooled Average-Profile and the Disparate-Profile Subgroup as compared to the Overall-Positive Profile Subgroup.

The above considerations suggest several tentative conclusions. Combining the systemic-wholistic approach with a lifespan perspective represents one promising endeavor to examine questions about the complex nature of heterogeneity and differential development in old age as well as about the sources underlying and the consequences arising from regularities and differences in development. The approach taken provided a complementary stance at the data available and thus revealed insights otherwise not gained. Keeping the difficulties in mind that are associated with studying subgroups of individuals (e.g., state-dependency, randomness, and fuzziness of classification), the present findings exemplify that this approach represents a heuristic tool to investigate structural and functional interdependencies. Hence, a systemic-wholistic perspective complements function-, element-, and mechanism-specific research in furthering our fundamental understanding of human development (P. B. Baltes & Smith, 1997).

5.4 Outlook

Future research on heterogeneity and differential development in old age will profit from and contribute to conceptual as well as methodological advancements. Conceptual efforts may be aimed at establishing a broader and more integrative theoretical framework

and clarifying the mechanisms underlying differential development. Methodological progress involves both planning and analysis decisions.

Conceptually, combining a lifespan perspective with a systemic-wholistic approach can be helpful in developing the foundation of an overarching theoretical framework for individual functioning and development (Smith & Baltes, 1997). So far, psychological research lacks an integrative conceptual and measurement scheme that could serve as a unified frame of reference. For example, the psychological dimensions used in this study represent different theoretical agendas and independently developed measurement spaces. A systemic-wholistic view on differential development (in the second half of life) is rare and there has been little systematic conceptual effort aside from general conceptions such as models of successful aging (e.g., P. B. Baltes & Baltes, 1990; Rowe & Kahn, 1997; Ryff & Singer, 1998). Advancement in this context may in the future serve as the basis for the establishment of a unifying standard of reference for both theoretical development and empirical research.

More conceptual and empirical work is needed that specifically aims at the mechanisms underlying and the consequences resulting from heterogeneity and differential development over time. Lifespan scripts about the developmental contexts, the evolutionary and ontogenetic foundations of development and its complex nature (P. B. Baltes et al., 1998) provide a conceptual backdrop for designing studies about heterogeneity and differential development in old age from a broad and systemic perspective. These lifespan scripts, for example, suggest that individuals in their eighties are particularly at risk to show functional decline over time. As a consequence, research that explicitly focuses on this and other potential transition periods may inform us about phases of life in which sources of differential development are turned on, added to, multiplied, or diminished (Dannefer, 1984; Finch, 1996; Smith, 1999; Vaupel et al., 1998).

It would also be interesting to put more effort into exploring how biological and cultural determinants of development converge at the level of non-normative classes of developmental influences. This involves the examination of how idiographic constellations of developmental contexts such as critical life events (e.g., bereavement) and chronic illnesses multiply or diminish individual differences in functioning and its change over time. Also, of major relevance are studies that explore the increasingly small potentials that cultural means have to compensate for biological decline in advanced old age and so contribute to maintaining a balance between gains and losses. Because the overall net sum of gains and losses can be brought about by very different constellations and constituting profiles of functioning

(Smith, 2003a; Dixon & Bäckman, 1995), the efficacy of cultural means for specific domains of functioning may vary between (subgroups of) individuals.

The research field may also profit from applying a dynamic-systems perspective. For example, proponents of such an approach would argue that some configurations or patterns of functioning can be expected to be more frequent than others because only a small number of system states are in some sense optimal and lead to stable behavior of the system (for application in biology, see Colinvaux, 1980, cf. Bergman & Magnusson, 1997). In this regard, research on maintenance and decline of functional profiles over time may be elucidated by the allostatic load concept, which indexes the systemic and cumulative wear and tear on the body through attempts to adapt (McEwen & Stellar, 1993). The present study provides a useful first step in the endeavor to go beyond an initial descriptive step and to examine underlying mechanisms, but there are many more age-graded, history-graded, and idiosyncratic factors that could be examined to be potentially of causal relevance.

With regard to underlying processes, it was, for example, not possible to disentangle whether subgroup differences in mortality hazards were also accompanied by differences in health behaviors and causes of death. Conceptions that specifically attempt to address some of the underlying mechanisms such as the Health Action Process Approach (HAPA; Schwarzer, 1992) may represent a promising future road. Individuals and subgroups may differ from one another in factors that are involved in the motivation phase and in the maintenance phase of health behaviors, and the accumulation of these differences may underlie differences in mortality. In the motivation phase, classic theories of social control (e.g., Durkheim, 1951) may be used to argue that a group of socially embedded elderly can be expected to form more stringent intentions to adopt health behaviors than a group of people with few social contacts. This is so because social support may help in establishing outcome expectancies (e.g., subjective norms or normative beliefs), which act as perceived social pressure of significant others. In the maintenance phase, social support can also be expected to be beneficial and future research may examine how groups of individuals differ in self-regulative processes of action plans and action control that may explain why some people maintain favorable behaviors over time or recover from setbacks and others do not. In general, if mechanisms were found to be different among subgroups of individuals, substantive practical implications arise. Interventions were required to be specifically tailored to subgroup needs. In the context of the present study, participants in the subgroup that was cognitively fit, but reported high neuroticism and loneliness (Disparate Profile) certainly profit

much more from interventions addressing social and self-regulatory competencies than both other subgroups.

Enhancements of research on heterogeneity and differential development may also result from refining the design of traditional longitudinal studies. Planning decisions in this regard may involve not only an in-depth focus on persons who are at risk to show differential development over time (e.g., oldest old), but also a measurement burst design (Nesselroade, 1991). The term measurement burst refers to the length of the time interval between occasions and suggests to complement traditional large-scale longitudinal designs by multiple measurements over relatively short periods of time such as months, weeks, or even days (see also Hultsch & MacDonald, 2004; Martin & Hofer, 2004). The particular benefits of combining a measurement burst design with systemic-wholistic thinking can be illustrated as follows. To begin with, such a design may allow researchers to disentangle short-term fluctuations from long-term enduring changes. Short-term fluctuations can then specifically be investigated in subgroup membership in that people may transit in and out of different states of disability (Manton & Land, 2000; Manton et al., 1997). If sufficiently enough individuals in their late eighties and older were examined, lifespan scripts about the decreasing robustness of the system in very old age (P. B. Baltes & Smith, 2003) can be examined: Fluctuations are expected to be more pronounced and domain-generalized (rather than domain-specific) among oldest-old participants than among the young old. Subsequently, fluctuations can be linked to variables that may have acted as antecedents, covariates, or consequences to further tease out differences in vulnerabilities for instability.

Recent advances in pattern-oriented methods such as growth mixture modeling with latent trajectory classes (Muthèn, 2001; see also Nagin, 1999) may, at least in the long run, help to overcome some of the longstanding problems associated with rather traditional pattern-oriented techniques. For example, Muthèn's methodology explicitly allows for qualitatively different change trajectories between the latent classes and estimates an individual's degree of membership in different classes. A systemic-wholistic perspective can not only be implemented by opting for such bottom-up strategies, but also by a top-down approach. Theoretical criteria developed in the MacArthur Studies of Successful Aging (Rowe & Kahn, 1997) can be used to define subgroups of individuals in old age into pre-determined categories that summarize levels of psychological and physical health relative to norms based on age and cohort membership.

Future work may also explore in more detail the various time schedules needed to examine development in different domains of functioning (Lerner, 1986) and in different phases

of life (e.g., Third Age vs. Fourth Age). In this context, additional insights can be gained from modeling developmental change in old age not in the traditional way as a function of 'time in study' or 'chronological age', but by using different time scales such as the 'onset of decline trajectories.' If information about psychological profiles or its change over time is related to onset of disease or to mortality, continuities and discontinuities in old age may best be captured by organizing the basis function not by chronological age, but by time to diagnosis or distance from death (for discussion, see Hertzog & Nesselroade, 2003; Sliwinski et al., 2003). Such mapping may reveal more similarities between individuals than is evident from traditional modeling approaches (P. B. Baltes & Graf, 1996). For example, recent work has demonstrated that participants who subsequently developed Alzheimer's disease showed accelerated memory decline much earlier than accelerated decline in speeded measures (Hall et al., 2001; see also Hall, Lipton, Sliwinski, & Stewart, 2000). In more general terms, these authors simulated that a specific subgroup of participants showed distinctly different trajectories of change in one time period than in others, and these trajectories were separated by qualitative events (i.e., change points) and differed from the trajectories of other subgroups. In this vein, one prospect for systemic-wholistic research on heterogeneity and differential development is to demonstrate the simultaneous operation of different causal mechanisms within different groups of the same sample.

The objective of the present dissertation was an exploration of some key questions of developmental psychology. The set of questions asked comprised the extent to which individuals and subgroups show common or differential patterns of development over time and its underlying mechanisms and outcomes. The current study focused on developmental processes in old age because much less is known about this phase of life as compared with earlier life phases such as childhood. Considering old age also allowed to delve into several conceptual and methodological challenges that are associated with an in-depth examination of heterogeneity and differential development. As research strategy, the dissertation study combined a lifespan perspective with a systemic-wholistic approach. It was demonstrated that this combination adds to our fundamental understanding of the nature and diversity of development in old age, the changing biological and environmental opportunities and constraints that shape individual development, and the potential late-life outcomes of development. Among the tentative conclusions to be drawn from this study is that this combination represents a heuristic tool to examine questions about structural and functional interdependencies among psychological, biological, and environmental domains. Hence, the approach taken complements research that is more function-, element-, and mechanism-specific.

