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Life Satisfaction Shows Terminal Decline in Old Age: Longitudinal Evidence from the German Socioeconomic Panel Study

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Abstract

Longitudinal data spanning 22 years, obtained from deceased participants of the German Socio-Economic Panel Study (SOEP; $N = 1,637$; 70 to 100 year olds), were used to examine if and how life satisfaction exhibits terminal decline at the end of life. Changes in life satisfaction were more strongly associated with distance to death than with distance from birth (chronological age). Multi-phase growth models were used to identify a transition point roughly four years prior to death wherein the prototypical rate of decline in life satisfaction tripled from –0.64 to –1.94 T-score units per year. Further individual-level analyses suggest that individuals dying at older ages spend more years in the terminal periods of life satisfaction decline than individuals dying at earlier ages. Overall, the evidence suggests that late-life changes in aspects of well-being are driven by mortality-related mechanisms and characterized by terminal decline.

Keywords

Selective mortality; successful aging; differential aging; German Socio-Economic Panel Study (SOEP); well-being

Lifespan psychological and gerontological research has long been interested in phenomena of terminal decline (Kleemeier, 1962; Palmore & Cleveland, 1976; Riegel & Riegel, 1972; Siegler, 1975). The general notion is that at some point shortly before death individuals' functioning declines quite rapidly. In various cognitive domains, evidence is building that late-life changes in function are marked by pronounced, proximate to death deteriorations

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(for review, see Bäckman & MacDonald, 2006). Only recently, however, have researchers begun examining how notions of terminal decline may apply to other aspects of psychological function such as well-being (Gerstorf, Ram, Röcke, Lindenberger, & Smith, 2007; Mroczek & Spiro, 2005). The present study uses 22-year longitudinal data from the nationally representative German Socio-Economic Panel Study to examine questions about terminal decline in old age in life satisfaction, a key component of well-being. Specifically, we (a) examine whether changes in life satisfaction occurring in old age are better characterized as age-related or mortality-related processes, (b) use multi-phase growth models to articulate and test notions of terminal decline, and (c) explore whether terminal decline may differ with age at death, sex, and education.

An accumulating body of empirical evidence suggests that low levels of functioning and pronounced decline on a number of psychosocial factors, including cognitive functioning and well-being, are predictive of subsequent mortality (e.g., Bosworth & Schaie, 1999; Danner et al., 2001; Ghisletta, McArdle, & Lindenberger, 2006; Levy, 2003; Lindenberger, Singer, & Baltes, 2002; Maier & Smith, 1999; White & Cunningham, 1988). When viewed next to evidence that well-being remains relatively stable throughout adulthood and old age (Diener, Lucas, & Scollon, 2006; Filipp, 1996; Kunzmann, Little, & Smith, 2000; Mroczek & Kolarz, 1998), unique associations between well-being and mortality seem paradoxical. Why, if not affected by normative late-life decline, is well-being related to impending mortality? One interpretation is that late-life changes in well-being may primarily be driven by mortality-related processes rather than age-related processes. The underlying idea is that individuals typically have enough resources to maintain a sense of well-being, even as they face increased risks for losses in the social and health domains (i.e., normative age-related decline). As death approaches, however, individuals are faced with additional mortality-related burdens that make it increasingly difficult to maintain well-being – and the system collapses. If this speculation is true, intraindividual changes in well-being occurring in the last years of life would be more closely associated to distance to death rather than distance from birth (i.e., chronological age).

Notions of terminal decline, as most often presented in the cognitive domain (for review, see Bäckman & MacDonald, 2006), would predict a multi-phase sequence wherein individuals will transition from a "pre-terminal" phase of normative gradual decline in functionality to a "terminal" phase of pronounced decline when the burdens of an approaching death begin to "overwhelm" a limited pool of resources (Kleemeier, 1962; Sliwinski et al., 2006). In recent years, empirical investigations of terminal decline phenomena have taken advantage of methodological innovations that allow fitting of growth curve models that articulate with specificity if and how intraindividual changes might be characterized by multiple phases of change (for in-depth discussions of spline or multi-phase growth models, see Cudeck & Harring, 2007; Cudeck & Klebe, 2002; Hall, Lipton, Sliwinski, & Stewart, 2000; Ram & Grimm, in press; Raudenbush & Bryk, 2002; Singer & Willet, 2003). In the cognitive domain, for example, multi-phase growth models have been used to identify multiple phases of mortality-related decline in perceptual speed and memory (Sliwinski et al., 2006; Wilson, Beck, Bienias, & Bennett, 2007; Wilson, Beckett, Bienias, Evans, & Bennett, 2003). Extending the approach to aspects of well-being, Gerstorf and colleagues (2007) used such models and longitudinal data from the Berlin Aging Study (of 70 to 100 year olds; Baltes & Mayer, 1999) to provide initial evidence that late-life intraindividual changes in life satisfaction are also characterized by terminal decline trajectories. More specifically, terminal-decline representations of change, characterized by a multi-phase model with a discrete shift to a two-fold increase in steepness of decline at about four (± 2.5) years prior to death, were found to provide for better and more efficient descriptions of the data than did linear representations over both chronological age and distance to death. In the absence of other studies on terminal decline of life-satisfaction, the purpose of the present study is to replicate and extend those initial findings.

The terminal decline hypothesis makes specific predictions that intraindividual changes can be structured along a transition from a "pre-terminal" phase of normative gradual decline into a "terminal" phase of pronounced decline shortly before death (Kleemeier, 1962; Sliwinski et al., 2006). However, the theory on terminal decline, in our reading, has remained vague regarding *when* the transition to terminal decline should occur (e.g., Kleemeier, 1962; Palmore & Cleveland, 1976; Riegel & Riegel, 1972; Siegler, 1975). The limited evidence from studies of terminal decline in cognition and life satisfaction has located transition points in a window ranging from 2 to 6 years (Gerstorf et al., 2007; Wilson et al., 2003, 2007) or even 8 years (Sliwinski et al., 2006) prior to death. The present study contributes to this exploration. Using a nationally representative sample and multi-phase growth models wherein the point of transition is estimated directly from the data, we examine when, in relation to death, a terminal phase of decline in life satisfaction may begin.

It is largely an open question whether men and women or individuals who die at earlier ages vs. those who die at later ages experience the last years of life differently. For example, the seminal Riegel and Riegel (1972) hypothesis suggests that decline might be diminished among the very old (e.g., 85+ years) as a result of more random causes of death. However, Bäckman and MacDonald (2006) concluded, in their review of the terminal decline literature from the cognitive domain, that, if anything, the evidence suggests the opposite – that mortality-related declines in advanced old age are actually greater as opposed to smaller. Similarly, in the well-being domain,Gerstorf et al. (2007) found the extent of terminal decline in life satisfaction to be most pronounced among individuals older than age 85. Thus, the general pattern of results appears consistent with the view that self-protective processes associated with maintaining function or well-being become increasingly vulnerable as individuals get older (Baltes & Smith, 2003; Smith & Gerstorf, 2004). In a related vein, other individual difference characteristics such as high educational attainment, low comorbidities, and preserved cognitive functioning may provide additional resources that might protect against late-life functional decline. However,Gerstorf et al. (2007) reported that all of these well-established mortality predictors accounted for only a very small portion of interindividual differences in terminal change in life satisfaction. The present study re-examines such relationships in the context of participants drawn from a nationally representative study. Specifically, we note if and how age at death, sex, and education are associated with individual differences in mortality-related life satisfaction changes. While not having specific hypotheses as to potential sex and education differences, we expect that impending mortality has more detrimental effects on functionality at older ages.

To summarize, the present study attempts to replicate and extend recent findings on mortality-related changes in life satisfaction in old age. We (a) determine whether mortality-related (distance-to-death) models of late life changes in life satisfaction provide better representations of the observed changes in old age than do age-related models; (b) use multi-phase representations of change (i.e., spline growth models) to articulate terminal decline hypotheses and derive an empirically-based location for the transition into terminal decline of life satisfaction; and (c) examine if and how the changes in life satisfaction occurring at the end of life differ with age at death, sex, and education.

Method

Growth curve models were fitted to 22 waves of yearly (1984–2005) longitudinal data from now deceased, 70 to 100 year old participants (*N* = 1,637) in the German Socio-Economic Panel Study (SOEP; Wagner, Frick, & Schupp, 2007) in order to examine intraindividual change in life satisfaction as a function of age or distance-to-death. Descriptions of the larger SOEP study, its design, participants, variables, and assessment procedures can be found in Haisken-De New and Frick (2006) and Wagner et al. (2007). Select details relevant to the present study are given below.

Sample and Participant Selection

The SOEP is a nationally representative longitudinal annual panel study of private households and individuals. In total, up to now the SOEP spans 22 years, 1984 to 2005, and has a participant base of roughly 25,000 persons that includes residents of both former West and East Germany, immigrants, and resident foreigners. When recruited, in either 1984, 1990, 1995, 1998, 2000 or 2002, participants were drawn at random from a set of randomly selected locations within Germany (for the random-walk recruitment methodology see Thompson, 2006). Response rates were sufficiently high (between 60% and 70%) that the demographic characteristics of the total sample are comparable to the wider population living in private households of Germany (Haisken-De New & Frick, 2006). Longitudinal attrition has been relatively low (4–14% yearly attrition across various subsamples), in part due to small rewards for continued participation (e.g., small gifts and information about results) and efforts to maintain regular contact with participants, including those who had missed one or more of the yearly assessments (Kroh & Spieβ, 2006). Data was collected via face-to-face interviews, or, for about 10% of respondents who had already participated multiple times, via self-administered questionnaires.

For the purposes of the present gerontologically-oriented study, we used data collected from 1,637 participants (727 men, 910 women) who were (a) aged 70 years or older at one or more assessments, and (b) who have since died. These select participants (decedents) were born between 1888 and 1935 and died, on average, 81.82 years later (*SD* = 6.54; range: 71–101 years). On average, they participated in 7.61 (*SD* = 5.68) annual surveys, and their deaths occurred 9.34 years (*SD* = 5.63; range: 1–22 years) after their initial assessment and 1.73 years (*SD* = 2.13; range: 0–15 years) after the last assessment in which they took part. In total, participants contributed 10,162 observation points that simultaneously span the 70 to 100 year age range (*mean* = 78.20, *SD* = 5.88) and the correspondent 22 to 0 years (*mean* = 5.58, *SD* = 3.99) prior to death.

Measures

Life satisfaction—As part of the yearly, and primarily economic, survey, individuals responded to the question "Wie zufrieden sind Sie gegenwärtig, alles in allem, mit ihrem Leben?" (translated as, "How satisfied are you with your life, all things considered?", see also Fujita & Diener, 2005; Kroh, 2006; Zimmermann & Easterlin, 2003) on a 0 to 10 ("totally unsatisfied" to "totally satisfied") scale. As a reflection about life as a whole, rather than the experience of pleasant emotions, answers are taken as an indication of *life satisfaction* (cf. Fujita & Diener, 2005) and considered an assessment of cognitive-evaluative (rather than emotional) aspects of well-being (Diener, Suh, Lucas, & Smith, 1999).[1] Life satisfaction scores were, on average, 6.66 (*SD* = 2.31, range = 0 to 10), indicating, in line with previous studies (Diener & Diener, 1996) and with the larger SOEP sample (Lucas, Clark, Georgellis, & Diener, 2003), that on the vast majority of occasions (8,669 of 10,162, 85%) the older, and now deceased, participants in the present study reported their life satisfaction to be at or above 'neutral'. For convenience of interpretation, life satisfaction scores were standardized to a *T* metric (*mean* = 50; *SD* = 10) using the entire SOEP longitudinal sample as the reference frame (mean = 7.02, *SD* = 1.55, see Lucas et al., 2003). For reference, a ‘neutral’ response on the original 11-point Likert-type scale would equal 37 on our T-unit scale. Further details of the life satisfaction item as used in the SOEP and its measurement properties can be found in Fujita and Diener (2005) and Kroh (2006).

Time metrics of age and distance-to-death—A major interest in this study was determining whether the observed long-term longitudinal changes in life satisfaction were better characterized as age-related or mortality-related processes, that is, over age or distance-to-death time dimensions. *Age*, at each assessment, was taken as the number of years since an individual’s birth (centered at 85 years). *Mortality* status and year-of-death for deceased participants was obtained either by (a) interviewers at the yearly assessments (i.e., from household members, or in the case of one-person households, neighbors), or (b) from city registries and other authorities (comprehensive data-base information was obtained most recently in 2001, see Infratest Sozialforschung, 2002). Comparisons of death rates and ages of death in the SOEP with those obtained from official life tables suggest that the sample is representative of German adult mortality (see Brockmann & Klein, 2004; Burkhauser, Giles, Lillard, & Schwarze, 2005). For ethical and legal reasons, the timing of individual deaths was only recorded by year (rather than by day and month). *Distance-to-death* (*DtD*) was calculated post-hoc as the difference between the date of the assessment and the participant’s death year. Additional demographic variables include, *age at death*, *sex* and years of formal *education*.

Data Analysis and Structure

To address the research questions regarding the structure of intraindivdual changes in life satisfaction, we examined both age- and mortality-related representations of change. Specifically, relative fits of single and multi-phase growth models across age and distance-to-death time dimensions were evaluated and compared. In follow-up analyses, we explored interindividual differences in terminal decline with respect to individual difference characteristics including age at death, sex, and education.

Age-related vs. mortality-related and linear vs. multi-phase representations of change—The main analytic task was to determine which time dimension, chronological age or distance-to-death, provided for a better representation of the observed longitudinal changes in life satisfaction. Two sets of growth curve (i.e., multilevel) models were used to model interindividual differences in change over time (McArdle & Nesselroade, 2003; Singer & Willett, 2003). In the first set of models, age was used as the time variable, effectively modeling interindividual differences in how each individual’s life satisfaction changed from age 70 to age 100. In the second set of models, distance-to-death was used as the time variable, modeling how life satisfaction changed in relation to impending mortality (i.e., in the 22 years prior to death). Within each model set, *linear* and *multi-phase* representations of intraindividual change were fitted, the former being used to represent continuous trajectories and the latter discrete shifts in the rate of change that occur at a specific age or distance-to-death. Comparing the relative fit of these models, we determined which time metric and type of trajectory provided a better representation of the data.

The *linear* model was specified as

[1]Note that a number of the other investigations of age-related changes in well-being focus on emotional (e.g., positive and negative affect; Charles et al., 2003; Mroczek & Kolarz, 1998) aspects of well being rather than cognitive-evaluative aspects as done herein, and some examine both emotional and cognitive aspects (e.g., Diener & Suh, 1998; Lucas & Gohm, 2000). Due to constraints of the data, we examine only the latter.

$$ls_{it}=b_{0i}+b_{1i}(time_{it})+e_{it}, \quad (1)$$

where person *i*'s reported life satisfaction at time *t*, ls_{it}, is a function of an individual-specific intercept parameter, b_{0i}, an individual-specific slope parameter, b_{1i}, that captures the rate of change over the selected time dimension (age or distance-to-death), and residual error, e_{it}. Following standard multilevel or latent growth modeling procedures (e.g., McArdle & Nesselroade, 2003; Ram & Grimm, in press; Raudenbush & Bryk, 2002; Singer & Willett, 2003), individual-specific intercepts, b_{0i}, and linear slopes, b_{1i}, (from the Level 1 model given in Equation 1) were modeled as

$$\begin{aligned} b_{0i}&=a_{00}+u_{0i}, \text{ and} \\ b_{1i}&=a_{01}+u_{1i}, \end{aligned} \quad (1a)$$

(i.e., Level 2 model) where interindividual differences, u_{0i} and u_{1i} are assumed to be normally distributed, correlated with each other, and uncorrelated with the residual errors, e_{it}.

The *multi-phase* model was used to articulate the hypothesis that, in the course of development, individuals transition between two phases of change. The linear model given above was extended to include a second slope parameter, b_{2i}, and a point of transition or 'change-point', *k* (see also Cudeck & Harring, 2007; Cudeck & Klebe, 2002, Willett & Singer, 2003). The model was specified as

$$\begin{aligned} ls_{it}&=b_{0i}+b_{1i}(time_{it}-k)+e_{it}, \quad \text{when } time_{it}<k, \text{ and} \\ ls_{it}&=b_{0i}+b_{2i}(time_{it}-k)+e_{it}, \quad \text{when } time_{it}\geq k, \end{aligned} \quad (2)$$

where individual-specific rates of change across the time points before the transition or 'change-point' *k* (e.g., pre-terminal phase) are captured by b_{1i}, and individual-specific rates of change across time points falling after the 'change-point' (e.g., terminal-phase) are captured by b_{2i}. The point of transition from one phase to the other, *k*, is a free (fixed effect) parameter estimated from the data, with b_{0i} capturing the estimated level of life satisfaction at this point in time. As in the linear model, interindividual differences were modeled using Level 2 equations where u_{0i}, u_{1i}, and u_{2i} are assumed to be normally distributed, correlated with each other, and uncorrelated with the residual errors, e_{it}. Models were fit to the data using SAS (Proc Mixed and Proc NLMixed; Littell, Miliken, Stoup, & Wolfinger, 1996). Of interest was (a) if age-based or distance-to-death based models provided for a better representation of the data; and (b) if there was evidence for multiple phases of decline (i.e., better overall fit to the data for the multi-phase models as compared to the linear models), and at what age or distance-to-death the transition between phases (i.e., the 'change-point', *k*) might occur.

Interindividual differences—One constraint of the multi-phase model given above is that the 'change-point', *k*, is fixed (assumed) to be the same for all individuals. Theoretically, however, individuals may transition into the terminal decline phase at different times, some individuals 2 years before death, some 4 years before death, etc. (cf. Baltes & Smith, 2003). As an initial exploration into whether such interindividual individual differences in the onset of terminal decline might be identified, an expanded model was fit to a subset of the data (i.e., a set of individuals who provided a large number of longitudinal observations, ~12+ observations; *n* = 400). Specifically, *k*, was reconceptualized as a random effect, k_i, in the within-person Level 1 model,

$$ls_{it}=b_{0i}+b_{1i}(time_{it}-k_i)+e_{it}, \quad \text{when } time_{it}<k_i, \text{ and}$$
$$ls_{it}=b_{0i}+b_{2i}(time_{it}-k_i)+e_{it}, \quad \text{when } time_{it}\geq k_i, \tag{3}$$

with interindividual differences in the ‘change point’, k_i, being modeled, along with b_{0i}, b_{1i}, and b_{2i}, at Level 2. Of particular interest was the extent of individual differences in the point of transition to terminal decline (i.e., variance of k_i). Statistical estimation was conducted via Gibbs sampling in WinBugs (Spiegelhalter, Thomas, Best, & Lunn, 2007; for model details see also Cudeck & Harring, 2007; Cudeck & Klebe, 2002; Wang & McArdle, in press).

Interindividual differences in the location of the change point (k_i) were then modeled as a function of individuals demographic variables, Of interest was if and how the modeled interindividual differences in the location of the change point were related to interindividual differences in age at death, sex, education, and their interactions, e.g.,

$$\begin{aligned} k_i=a_{03}+a_{13}(age\ at\ death_i) \\ +a_{23}(sex_i) \\ +a_{33}(education_i) \\ +a_{43}(age\ at\ death_i \times education_i) \\ +a_{53}(age\ at\ death_i \\ \times sex_i) \\ +a_{63}(sex_i \\ \times education_i) \\ +a_{73}(age\ at\ death_i \\ \times sex_i \\ \times education_i)+u_{3i}. \end{aligned} \tag{4}$$

Data structure—Descriptive statistics for life satisfaction are provided in Table 1, over chronological age (left-hand panel) and distance-to-death (right-hand panel). At the sample level, mean levels of life satisfaction appear to decrease with age (e.g., *mean* = 48.05 for age 70, *mean* = 32.13 for age 99) and proximity to death (e.g., *mean* = 50.23 for observations taken 20 years prior to death, *mean* = 41.14 for the year prior to death). It may also be noted from Table 1 that over 85% of the assessments were obtained when participants were in their 7th ($n_{observations}$ = 6,335) and 8th decades of life (n_o = 3,380) or in the 10 to 5 year (n_o = 2,906) and 5 to 0 year (n_o = 5,941) periods prior to death. Further, we note that 88% or 1,447 of the 1,069 deceased participants contributed information about intraindividual change by providing two or more data points (*M* observation period = 6.13 years, *SD* = 5.16; range: 0–21 years), some in the “early” years (e.g., 70 to 75 years of age), others in the later years (e.g., in the four years prior to death). Following the accelerated longitudinal design, aligning all of these segments and treating them as a single sample allowed for estimation, under missing-at-random assumptions (Little & Rubin, 1987), of an age gradient spanning 30 years (70 to 100) and a distance-to-death gradient of up to 22 years. Finally, the correlation between age and distance-to-death was of moderate size (r = .27, p < .001). In sum, the data structure suggests only partial overlap between the two time dimensions and that model inferences are most relevant for the 70 to 90 age span and/or the decade prior to death.

Results

Comparing Age-Related and Mortality-Related Changes in Life Satisfaction

Before examining age-related and mortality-related changes in life satisfaction, we checked the relative amount of between-person and within-person variance in the data. The intra-class correlation was .48 (as computed using a random intercept-only model). In other words, 48% of the total variation in life satisfaction was between-person variance, with the remainder (52%) being within-person variation. The data thus appeared to contain both substantial amounts of between-person differences and within-person variation over time. Noting that there was indeed intraindividual variation to model, four growth models, 2 types of change (linear and multi-phase) × 2 time metrics (age and distance-to-death), were used to describe and evaluate how the noted changes in life satisfaction were structured over time.

Linear models—Parameter estimates and fit statistics for the linear models, with either age or distance-to-death as the time metric, are presented in Table 2. The mortality-based, distance-to-death model provided a better fit to the data, as evaluated by relative overall model fit criteria (AIC = 80,008 for the age model, AIC = 79,645 for the distance-to-death model, lower AIC indicates better relative model fit). Additionally, better fit was also evaluated with regard to the additional amount of explained variance, formally conceptualized as the proportional reduction of prediction error (i.e., change in pseudo R^2), when either age or distance-to-death was added to the within-person (Level 1) portion of the model (Snijders & Bosker, 1999).[2] The change in pseudo-R^2 was 0.170 for the distance-to-death metric as compared to 0.142 for the age metric. Taken together, both relative overall model fit and proportion of explained variance suggest that distance-to-death provides a significantly better fitting and more efficient description of longitudinal changes in life satisfaction aspects of our data than does chronological age. We also note that, on average, the age model shows significant age-associated decline (− 0.63 T-score units per year), while the distance-to-death model shows a relatively more pronounced mortality-associated decline (− 1.02 T-score units per year).

Multi-phase models—Subsequently, models incorporating multiple phases of change (i.e., Equation 2), over both age and distance-to-death time metrics, were examined. Our intent was to empirically evaluate if multi-phase models of change were better than single-phase models of change. Parameter estimates and model fit indices are reported in Table 3. The multiple-phase models provided better fit to the data, for both age-based (AIC = 79,917) and distance-to-death (AIC = 79,445) time metrics, than the linear counterparts (AIC = 80,008 and AIC = 79,645, respectively). Over chronological age, prototypical change was characterized by a decline of − 0.47 T-units per year up until age 81.23 years (*SE* = 0.39), where the rate of decline "accelerated" to − 0.56 T-units per year. These parameters suggest that normative intraindividual decline in life satisfaction may be somewhat more pronounced in very old age (i.e., 85+ years of age) than in old age (i.e., 70 to 85 yeas of age). Over distance-to-death, prototypical multi-phase changes in life satisfaction (of the terminal decline type) were characterized by a "pre-terminal" decline of − 0.64 T-units per year and a transition at 4.19 years (*SE* = 0.17) prior to death to steeper "terminal" decline of

[2]Following the general framework outlined by Snijders and Bosker (1999, pp. 99–105), we calculated the explained proportion of within-person variance as

$$\Delta\text{pseudo} - R^2 = 1 - (\sigma^2_{\text{e(u)}}/\sigma^2_{\text{e(c)}}), \quad (5)$$

where $\sigma^2_{e(u)}$ is the residual within-person variance obtained from an unconditional or intercept-only model (for our data = 122.81) and $\sigma^2_{e(c)}$ is the parallel term from the conditional model that includes the time variable, age or distance-to-death (for our data 107.51 and 104.95, respectively). It was also noted that the inclusion of both time metrics only marginally increased the explained variance further (Δpseudo-R^2 = 0.173).

− 1.94 T-units per year. Further, as was the case for the linear models, comparison across time-metrics (i.e, age vs. distance-to-death), revealed that the distance-to-death time metric provided for better and more efficient representation of the intraindividual changes in life satisfaction and the interindividual differences therein (AIC = 79,917 for age vs. AIC = 79,445 for distance-to-death).[3]

Overall, the model closest to the terminal decline hypothesis, one that represented late-life changes in life satisfaction over a distance-to-death time metric as a transition between two phases, with the latter phase being characterized by steeper decline than the former, provided the best (of the models tested) fit to the data. Prototypical and model-implied intraindividual changes in life satisfaction for a random selection of 100 participants are shown in Figure 1. Prototypically, the rate of life satisfaction decline steepened at around four year prior to death by a factor of three. In addition to the fixed effects or "prototypical changes" noted above and in Table 3, the multi-phase distance-to-death model also included random effects (i.e., interindividual differences) in pre-terminal phase slopes (for the period more than 4.19 years prior to death, slope 1), terminal phase slopes (for the last 4.19 years of life, slope 2), and the level of life satisfaction at the point of transition (at exactly 4.19 years prior to death). There were significant interindividual differences in each (variances = 0.78, 9.11, and 128.60, respectively), and the pattern of covariances reflects that individuals who exhibited steeper pre-terminal declines tended to arrive at the transition phase at relatively lower levels of life satisfaction (σ_{u0u1} = 6.58 or in correlation units r_{u0u1} = 0.66). Further, individuals who arrived at low levels were somewhat more likely to exhibit shallower decline in the terminal phase (σ_{u0u2} = − 7.01 or r_{u0u2} = − 0.20). Rates of decline in the pre-terminal phase, however, were not significantly correlated with rates of decline in the terminal phase (σ_{u1u2} = − 0.16 or r_{u1u2} = − 0.06).

Interindividual Differences in Terminal Decline

To push the articulation of terminal decline from the notion of a population-level transition parameters toward individual-level transitions, we also explored possible interindividual differences in the location of the change point to more pronounced late-life decline in life satisfaction. To do so, we used data from a sub-sample of individuals who provided extensive longitudinal data and applied random effects change-point models (Cudeck & Harring, 2007; Cudeck & Klebe, 2002). The increase in model complexity required fitting only those individuals who had provided ~12+ observations (n = 400; 54% women; age at death, M = 81.60 years, SD = 6.66; range: 71–101). The left-hand panel of Table 4 reports results from a preliminary cross-validation check in that a fixed-effects change-point model fit to the n = 400 sub-sample revealed a similar pattern as reported above for the total sample of N = 1,637 (e.g., location of the change-point at 4.51 years vs. 4.19 years reported in Table 3). As can be obtained from the right-hand panel of Table 4, a model allowing for interindividual variation in the location of the change point provided better fit to our data better than the previous model setting the change point invariant across persons (DIC[4] = 30,454 vs. DIC = 30,345). Table 4 also reveals that all three model parameters were largely consistent with those found in the larger sample, although the average individual change point to terminal decline was somewhat closer to death (4.51 vs. 4.05 years prior to death). Most important for our question was the notable interindividual differences in the location of

[3]Consistent with our finding of increased steepness of decline prior to death, a model specifying linear and quadratic change in life satisfaction over distance-to-death was found to fit our data better ($-2LL$ = 79,470) than a model with linear change only ($-2LL$ = 79,633; $\Delta -2LL$ = 163). However, the two-phase model with a change point 4.19 years prior to death still provided better relative model fit than this single-phase model ($\Delta -2LL$ = 47). We also explored quadratic trends over chronological age, but these were not significantly different than zero (neither with nor without random effects for the quadratic component).

[4]DIC = Deviance Information Criteria is a measure of relative model fit, intended as a generalization of the AIC. Having used Gibbs sampling estimation to conduct the analysis we report the DIC generalization in leiu of the AIC. Interpretation of DIC is the same as with AIC, where lower values indicate a better relative model fit..

the change point, or *when* the onset of terminal decline occurred (σ^2_k = 11.53). To illustrate this finding, Figure 2 shows prototypical and model-implied intraindividual changes in life satisfaction for a random selection of 100 participants. from the subsample. While on average, this subset of individuals transitioned to the terminal phase at 4.05 years before death, some individuals entered earlier (e.g., six years prior to death), some later (e.g., one year prior), and some not at all.[5] In addition, the pattern of covariances suggests that individuals who exhibited steeper pre-terminal decline transitioned to the terminal phase of decline somewhat earlier (σ_{u1u3} = 1.06 or in correlation units r_{u1u3} = 0.35).

To examine how these differences in individuals' transition to the terminal-decline phase relate to interindividual difference characteristics, the location of the change point, k_i was regressed on age at death, sex, education, and their two-way and three-way interactions.[6] Results are presented in Table 5. There was no evidence of systematic differences by sex or levels of education, but age at death was related to the location of the change point (a_{13} = ???). Older age at death was associated with having spent more time in the terminal decline phase – this effect amounted to 29 more days per additional year lived (0.07 * 365 days) or eight more months per additional decade lived (0.70 * 12).

Discussion

The current study used 22-wave longitudinal data from deceased 70 to 100 year old participants in the German Socio-Economic Panel (SOEP) study to examine if life satisfaction exhibits terminal decline at the end of life. We found that individual differences in late-life intraindividual changes in life satisfaction were better described using a distance-to-death rather than distance-from-birth time metric. Specifically, of the four growth curve models tested, a model that articulated notions of terminal decline by incorporating two phases of change over distance-to-death provided the best fit to the data. This model revealed a transition point 4.19 years prior to death at which the prototypical rate of decline steepened from the pre-terminal phase to the terminal phase by a factor of three (from − 0.6 to − 1.9 T-units per year). Follow-up analyses indicated while men and women, and individuals of differing educational levels showed comparable late-life declines in life satisfaction, individuals who died at later ages tended to spend longer periods of time in terminal decline.

While varying somewhat across cultures and sub-groups, individuals, for the most part, report being happy or satisfied with their lives (Diener & Diener, 1996; Diener & Suh, 1998). For example, Lucas and colleagues (2003) found that the vast majority (88%) of the ~25,000 participants in the larger SOEP sample reported life satisfaction scores above "neutral" (i.e., > 5 on the 0 to 10 scale). Similarly, within the elderly and now deceased segment of the same sample used here, 85% of reports (8,669 of 10,162 observations) were at or above "neutral." When these 70 to 100 year olds were broken down by age and distance to death, however, we found systematic declines in life satisfaction such that average levels were below the neutral point at ages 97 to 99 years (see Table 1) and at death for individuals who died older than age 85 (intercept = 4.97, as revealed in a follow-up analyses where we re-calculated the above multi-phase model using the original scale units from 0 to 10). Thus, in this nationally representative sample from a highly developed country, a sizeable number of individuals in very old age and/or the last few years of life report being fairly unsatisfied. Without delving into whether such findings indicate that

[5]Individual change points were estimated to be at or after death for 66 individuals. Follow-up examinations of these individuals indicated that their data series were each better characterized by single-phase linear declines, rather than multi-phases – an indication that they did not ever enter a terminal decline phase.

[6]We also used age at death, sex, and education as well as their interaction terms as predictors of level, pre-terminal slope, and terminal slope. None of the covariates, however, were significantly related to these model parameters.

dissatisfaction with life might be equated with approaching death or the moral and ethical issues of whether society should knowingly tolerate decline below "neutral" levels of satisfaction (see Baltes, 2006), we simply observe, in the context of aging and longevity, that there appears to be a "soon to die" segment of the population that is indeed not happy. Whether or not such feelings can be alleviated should be examined further.

When examining if and how longitudinal changes in life satisfaction were structured, we found, somewhat in contrast with other reports in the literature, indications of age-related decline (e.g., Charles, Reynolds, & Gatz, 2001; Filipp, 1996; Kunzmann et al., 2000; Mroczek & Kolarz, 1998). The extent of decline in the present study (e.g., − 0.75 T-score units per year in the linear age-based model) was somewhat steeper than that found (or implied by cross sectional age differences) in several previous studies (e.g., − 0.33 T-score units per year in Gerstorf et al., 2007; no age differences across the lifespan in Diener & Suh, 1998 and Lucas & Gohm, 2000). This may have been due to our having only selected elderly participants (older than in most other studies) who were known to have died. To explore this possibility, follow-up analyses on all SOEP participants who provided data after age 70, independent of their mortality status (N = 3,519), revealed a somewhat shallower age gradient (− 0.54 T-units per year) that more closely parallels reports from other studies. In other words, there is some evidence that the mortality-based selection criteria (a criteria that will select everyone at some point) employed in this study contributes to the steepness of age-related decline in life satisfaction found here, as compared that found in other studies.[7]

Examining mortality selection processes explicitly, distance-to-death based models were found to fit the data relatively better than age-based models – providing further evidence that mortality-related processes may be a major influence on late-life changes in well-being. When viewed from this perspective, wherein change gradients are explicitly organized according to the selection criteria (e.g., death) we found that progressive processes leading to death may also be those that drive changes in life satisfaction occurring in old age. Parallel to evidence accumulating for various measures of cognitive functioning (for overview, see Bäckman & MacDonald, 2006) and recent reports on aspects of well-being from the Normative Aging Study (Mroczek & Spiro, 2005) and the Berlin Aging Study (Gerstorf et al., 2007), the present findings from the nationally representative SOEP study suggest that the within-person changes in well-being occurring in late life are structured as a mortality-related process. Impending death, thus, appears to represent progressive processes that encompass numerous domains.

Following the terminal decline hypothesis (e.g., Kleemeier, 1962; Sliwinski et al., 2006) multi-phase growth models were used to identify when individuals transition from a "pre-terminal" phase of normative gradual decline in functionality to a "terminal" phase of pronounced decline. Estimated to be roughly four years before death, the placement of the transition into terminal decline is largely consistent with both findings for the cognitive domain (8 years, Sliwinski et al., 2006; 4 years, Wilson et al., 2003) and recent evidence for life satisfaction decline from the Berlin Aging Study (4 years, Gerstorf et al., 2007). We also note consistencies with these earlier reports in that average terminal phase decline amounted to –1.94 T-units per year (earlier reports range between − 0.8 and − 2.2), three times the decline noted for the pre-terminal phase (earlier reports found the terminal phase to be between 2 to 12 times as steep).[8] Together, the transition point and rate of terminal decline suggest that, prototypically, individuals' life satisfaction declines nearly a full standard deviation, from roughly 48 to 40 on our T-unit scale (7 to 5.5 on the raw scale) during the

[7]When we further included only participants who have not died by the year 2005, we found an even shallower age gradient of − 0.43 [SE = 0.03], p < .001.

last four years of life. We emphasize, however, that all these previous reports (including our own) represent "average" population level estimates, and, in particular, make an assumption that the location of the transition point is invariant across individuals.

As an initial exploration into how the onset of terminal decline may differ across individuals, we examined differences based on age at death, sex, and education. Our analyses did not reveal differences related to sex and education, but we found that those dying at later ages appear to spend more years in the terminal decline phase (a difference of about eight months per additional decade lived). One interpretation is that individuals who survive into very old age are at the limits of their adaptive capacity and that the system of self-protective processes associated with maintaining well-being has become increasingly vulnerable in very old age (Baltes & Smith, 2003; Smith & Gerstorf, 2004). In other words, individuals in their 70s or early 80s may still have sufficient resources to ward off or delay the detrimental effects of impending mortality, while the very old cannot. Our cautious interpretation, perhaps still a speculation, is that it is not age per se that matters (for life satisfaction), but rather a combination of closeness to death and the age at which this closeness appears. Individual-based notions of distinguishing multiple phases in old age, for example, highlight that transitions from the "Third Age" to the "Fourth Age" are primarily linked to the maximum lifespan of a given *individual* and can thus occur at very different ages (e.g., around age 60 for some or around age 90 for others; see Figure 1 in Baltes & Labouvie, 1973, reprinted in Hertzog & Nesselroade, 2003; Baltes & Smith, 2003). Our findings indicate that the years prior to death are more dysfunctional (i.e., drawn out decline in life satisfaction) in older ages (see also Crimmins, 2001). It is noted, however, that this initial analysis of interindividual differences in terminal decline was in some ways "a theoretically informed exploratory analysis", driven in large part by the limitations of the data (e.g., relatively small number of variables; lack of information about cognitive functioning or cause of death). Although limited, we hope that it provides an initial look at if and how theoretical propositions regarding interindividual differences in terminal decline may be articulated, identified, and examined. Additionally, the multiphase random change-point model represents (and requires) some of the latest innovation in statistical estimation and remains at the edge of what is possible with currently available software (see Cudeck & Harring, 2007; Wang & McArdle, in press). While sure that these developments allow for more precise articulation of the theory (e.g., individual differences in onset of terminal decline), we still interpret the results with some caution. The initial evidence, though, suggests that further examinations with more advanced tools and extensive/intensive pre-death repeated measures data should be pursued.

We further note that the present examination remains descriptive and does not allow for any inferences regarding causality. Conceptually, it is an open question whether psychosocial factors can be construed as conveying mortality risks on their own or reflecting the effects of pathologic processes. Regarding well-being, for example, one position argues that self-evaluations of one's life and aging do have physiological effects on cardiovascular and immune functioning (Danner et al., 2001; Kiecolt-Glaser, McGuire, Robles, & Glaser, 2002; Pressman & Cohen, 2005) that may have long-term effects on functioning and survival. Another position argues that well-being ratings might represent evaluations that reflect quite accurate summary perceptions of an individual's level and change in functioning in a variety of other domains that are more directly linked to mortality (cf. Maier & Smith, 1999).

[8]Comparing standardized units across studies is, of course, open to debate given that standardizations depend upon sample characteristics. However, we opted for this approach in a first attempt to compare rates of terminal decline across studies and domains. In addition, Sliwinski and colleagues (2006) reported their results for episodic memory in raw data units, which does not allow for cross-study comparisons (range 0 – 72; pre-terminal decline: 0.77 raw-score units per year; terminal decline: 1.42 raw-score units per year).

Reports from the Berlin Aging Study, however, suggest that interindividual differences in terminal change in life satisfaction could not be accounted for by comorbidities or terminal decline in various aspects of cognitive functioning (Gerstorf et al., 2007). Unfortunately, we were unable to examine such questions with the data at hand (SOEP is primarily an economic study). Examining these and other etiological questions, however, would shed some initial light on potentially underlying mechanisms. For example, it is conceivable that various causes of death (e.g., cerebrovascular, cardiac, and cancer) and the conditions associated with the process of dying (e.g., institutionalization, frailty) may account for differential portions of individual differences in terminal decline of well-being.

Evidence has been building that events such as marriage and unemployment systematically drive short-term changes in individuals' life satisfaction (e.g., Lucas et al., 2003, 2004). The present study adds to these notions, suggesting that impending death may also contribute to a set of systematic changes in life-satisfaction, albeit ones that lead up to the "event" rather than away from it. We found evidence of structured terminal decline, and along with other recent studies, provide further evidence that proximity to death is associated with substantial losses not only in "age-sensitive domains," such as intellectual and sensory functioning, but also in "age-insensitive" domains, such as well-being, that are usually well preserved into old and advanced old age (see also Gerstorf et al., 2007; Mroczek & Spiro, 2005). As more and more data on the last years of life become available, and our analytical techniques become more refined, there is no doubt that we shall learn more about how and why mortality-related processes contribute to the experiences of late life – steps along the way to the greater goal of doing what we can to make the terminal years ones filled with the satisfaction of living a good life.

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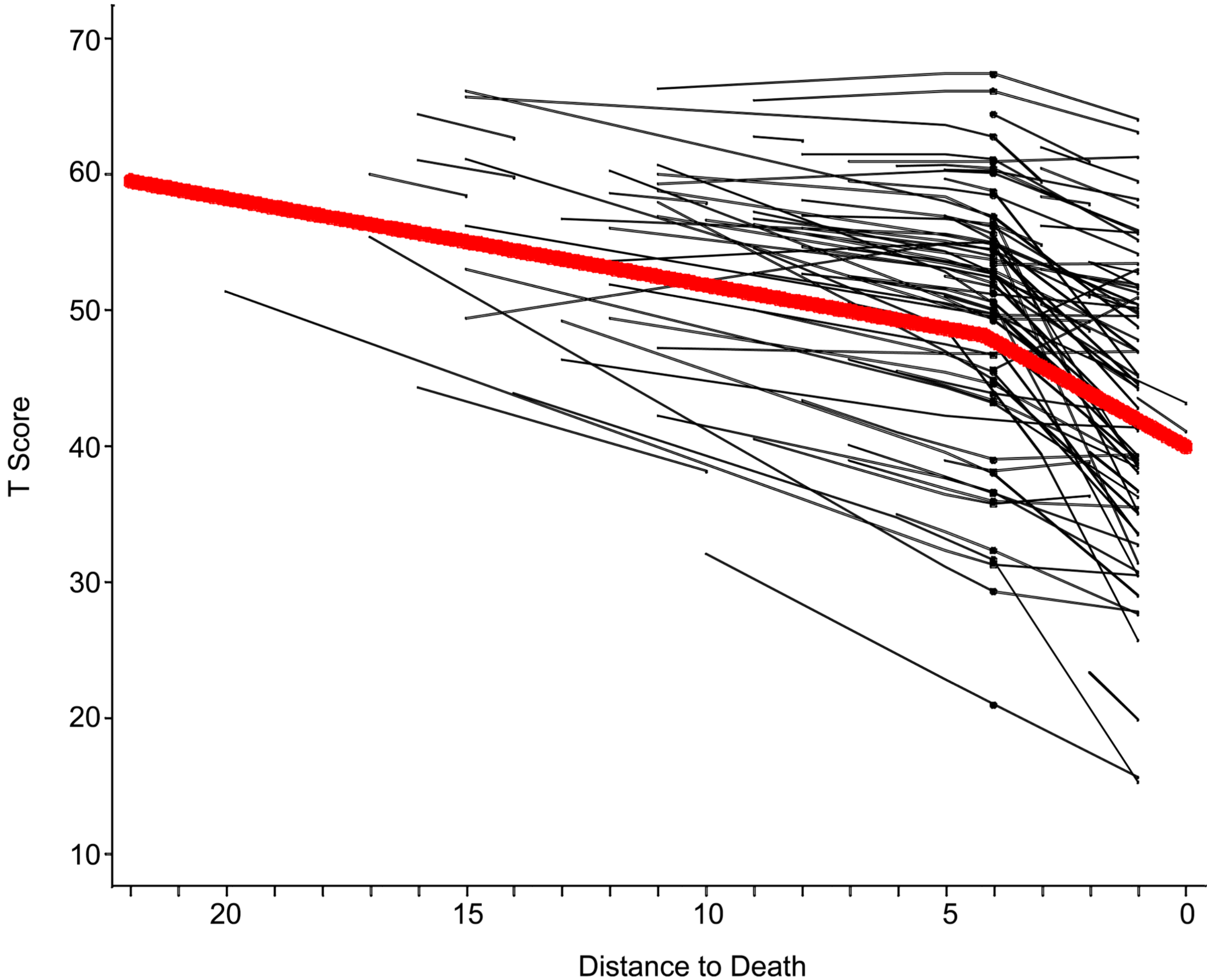

Figure 1.
Estimates from the optimal multi-phase growth model over distance-to-death in life satisfaction, as identified using 22-wave yearly longitudinal data from now deceased, 70 to 100 year old SOEP participants (*N* = 1,637; see right-hand panel of Table 3). Prototypical (thick line) and model-implied intraindividual changes in life satisfaction for a random selection of 100 deceased participants (thin lines) are shown. At a change point 4.19 years prior to death, the rate of decline steepened from the pre-terminal phase (− 0.64 T-Score units per year) to the terminal phase (− 1.94 T-Score units per year) by a factor of 3.

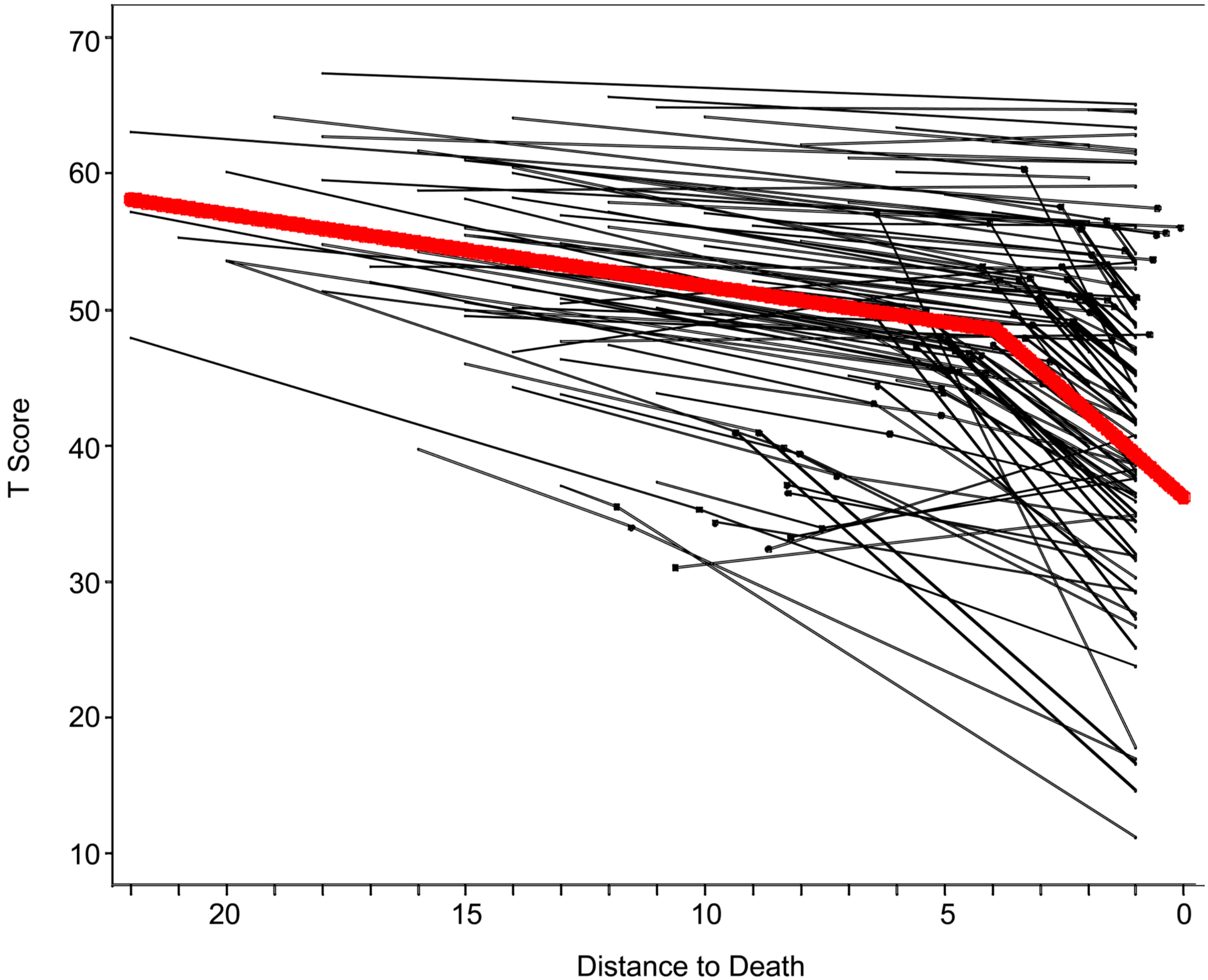

Figure 2.

Estimates from the optimal multi-phase growth model over distance-to-death in life satisfaction with interindividual differences in the change point, as identified in a subset of SOEP participants who provided a large number of longitudinal observations (~12+ observations; $n = 400$; see right-hand panel of Table 4). Prototypical (thick line) and model-implied intraindividual changes in life satisfaction for a random selection of 100 deceased participants (thin lines) are shown. Large interindividual differences in the location of the change point to more pronounced late-life decline in life satisfaction can be seen. While on average, this subset of individuals transitioned to the terminal phase at 4.05 years before death, some individuals entered earlier (e.g., six years prior to death), some later (e.g., one year prior), and some hardly or not at all.

Table 1

Descriptive Statistics for Life Satisfaction over Age at Assessment and Distance to Death.

Life Satisfaction							
Chronological age				Distance-to-death (DtD)			
Age	***n***	***M***	***SD***	**DtD**	***n***	***M***	***SD***
70	634	48.05	15.05	22	4	59.55	11.17
71	660	48.72	14.57	21	10	49.87	13.26
72	663	48.85	14.28	20	18	50.23	9.76
73	666	47.99	14.91	19	26	53.10	12.54
74	647	48.47	14.34	18	37	49.70	14.94
75	642	47.88	14.94	17	54	53.10	12.58
76	636	49.12	14.98	16	79	52.81	12.89
77	629	48.55	14.61	15	119	53.02	12.25
78	606	46.65	14.97	14	157	53.82	11.31
79	552	48.18	15.33	13	207	54.02	11.85
80	520	47.48	14.82	12	263	52.42	12.38
81	474	46.77	15.65	11	341	52.80	12.76
82	444	47.60	14.76	10	402	51.30	13.57
83	402	47.53	14.80	9	484	50.86	13.68
84	360	47.29	14.33	8	567	49.27	14.15
85	316	46.83	13.93	7	664	49.83	14.11
86	276	45.50	15.90	6	789	48.87	13.80
87	236	46.10	15.89	5	940	48.40	14.23
88	200	45.00	15.53	4	1101	47.24	14.83
89	152	46.69	13.47	3	1229	46.30	14.78
90	129	45.42	15.57	2	1365	45.30	15.45
91	92	46.29	16.41	1	1303	41.14	16.62
92	68	47.69	13.90	0	3	43.42	12.90
93	57	44.10	16.30				
94	36	43.96	16.13				
95	25	47.55	18.33				

Life Satisfaction							
Chronological age				Distance-to-death (DtD)			
Age	***n***	***M***	***SD***	**DtD**	***n***	***M***	***SD***
96	19	46.48	19.64				
97	8	34.55	18.87				
98	8	35.35	15.33				
99	4	32.13	23.19				
100	1	56.32	–				

Note. N = 1,637 who provided 10,162 observations. Scores standardized to a T metric (*mean* = 50; SD = 10) using the entire SOEP longitudinal sample as the reference frame (mean = 7.02, SD = 1.55, see Lucas et al., 2003).

Table 2

Linear Growth Models for Life Satisfaction over Chronological Age and Distance-to-Death.

	Life satisfaction			
	Chronological age		Distance-to-death	
Parameter	**Estimate**	**SE**	**Estimate**	**SE**
Fixed effects estimates				
Intercept[1], a_{00}	42.10 ***	(0.45)	42.30 ***	(0.39)
Slope[2], a_{01}	− 0.63 ***	(0.04)	− 1.02 ***	(0.05)
Random effects estimates				
Variance intercept	159.78 ***	(10.82)	169.76 ***	(8.67)
Variance slope	0.65 ***	(0.08)	0.93 ***	(0.11)
Cov. intercept, slope	5.21 *	(0.80)	8.85 ***	(0.90)
Residual variance	107.51 ***	(1.74)	104.95 ***	(1.70)
Number parameters	6		6	
−2LL	79,996		79,633	
AIC	80,008		79,645	

Note. Unstandardized estimates and standard errors are presented.

[1]Intercept is centered at age 85 for age-based model, or at death for distance-to-death model;

[2]Slope or rate of change is scaled in T-units per year. N = 1,637 who provided 10,162 observations. Scores standardized to a T metric (*mean* = 50; *SD* = 10) using the entire SOEP longitudinal sample as the reference frame (mean = 7.02, *SD* = 1.55, see Lucas et al., 2003). *AIC* = Akaike Information Criterion; *−2LL* = −2 Log Likelihood, relative model fit statistics. Cov. = Covariance.

* $p < .05$,

*** $p < .001$.

Table 3

Multi-Phase Growth Models for Life Satisfaction over Chronological Age and Distance-to-Death.

	Life satisfaction			
	Chronological age		Distance-to-death	
Parameter	**Estimate**	**SE**	**Estimate**	**SE**
Fixed effects estimates				
Intercept[1], a_{00}	44.67 ***	(0.53)	48.14 ***	(0.42)
Change point, *k*	81.23 ***	(0.39)	4.19 ***	(0.17)
Slope 1[2], a_{01}	− 0.47 ***	(0.11)	−0.64 ***	(0.06)
Slope 2[2], a_{02}	− 0.56 ***	(0.06)	− 1.94 ***	(0.15)
Random effects estimates				
Variance intercept	181.23 ***	(12.08)	128.60 ***	(7.02)
Variance slope 1	2.11 ***	(0.43)	0.78 ***	(0.14)
Variance slope 2	1.38 ***	(0.18)	9.11 ***	(1.20)
Cov. intercept, slope 1	− 10.67 ***	(2.08)	6.58 ***	(0.88)
Cov. intercept, slope 2	9.45 ***	(1.25)	− 7.01 **	(2.04)
Cov. slope 1, slope 2	− 0.61 *	(0.26)	− 0.16	(0.32)
Residual variance	103.98 ***	(1.71)	97.49 ***	(1.66)
Number parameters	11		11	
−2LL	79,895		79,423	
AIC	79,917		79,445	

Note. Unstandardized estimates and standard errors are presented.

[1]Intercept is centered at the change point in both models;

[2]Slope or rate of change in T-units per year. $N = 1,637$ who provided 10,162 observations. Scores standardized to a *T* metric (*mean* = 50; *SD* = 10) using the entire SOEP longitudinal sample as the reference frame (mean = 7.02, *SD* = 1.55, see Lucas et al., 2003). *AIC* = Akaike Information Criterion; *−2LL* = −2 Log Likelihood, relative model fit statistics. Cov. = Covariance.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

Table 4

Multi-Phase Growth Models of Life Satisfaction over Distance-to-Death With Change Points as Fixed or Random (n = 400).

	Life satisfaction			
	Fixed-change point		Random-change point	
Parameter	**Estimate**	**SE**	**Estimate**	**SE**
Fixed effects estimates				
Intercept[1], a_{00}	47.50 ***	(0.74)	48.69 ***	(0.98)
Change point, *k* or a_{03}	4.51 ***	(0.38)	4.05 ***	(0.92)
Slope 1[2], a_{01}	− 0.56 ***	(0.07)	− 0.51 ***	(0.08)
Slope 2[2], a_{02}	− 2.18 ***	(0.27)	− 3.31 ***	(0.73)
Random effects estimates				
Variance intercept	128.90 ***	(12.21)	83.23 ***	(15.97)
Variance change point	n. e.		11.58 **	(4.31)
Variance slope 1	0.60 ***	(0.14)	0.26 *	(0.12)
Variance slope 2	6.49 **	(1.98)	5.34 *	(2.67)
Cov. intercept, change point	n. e.		17.50 ***	(3.85)
Cov. intercept, slope 1	6.14 **	(1.11)	2.90 **	(1.02)
Cov. intercept, slope 2	− 5.50	(2.94)	− 15.82 **	(4.84)
Cov. Change point, slope 1	n. e.		1.06 ***	(0.28)
Cov. Change point, slope 2	n. e.		− 2.89	(2.06)
Cov. slope 1, slope 2	0.04	(0.32)	− 0.75	(0.57)
Residual variance	88.03 ***	(2.31)	88.18 ***	(2.57)
Number parameters	11		15	
DIC	30,454		30,345	

Note. Unstandardized estimates and standard errors are presented.

[1]Intercept is centered at the change point in both models;

[2]Slope or rate of change in T-units per year. Scores standardized to a *T* metric (*mean* = 50; *SD* = 10) using the entire SOEP longitudinal sample as the reference frame (mean = 7.02, *SD* = 1.55, see Lucas et al., 2003). *DIC* = Deviance Information Criterion, relative model fit statistic. n. e. = not estimated. Cov. = Covariance.

* $p < .05$,

** $p < .01$,

*** $p < .001$.

Table 5

Multiple Regression of Interindividual Differences in the Location of the Change Point On Demographic Characteristics (n = 400).

	Change point	
Predictor	***B***	***SE***
Intercept	3.962 ***	0.286
Age at death	0.071 *	0.033
Sex	0.719	0.392
Education	− 0.008	0.184
Age at death × sex	0.076	0.049
Age at death × education	0.007	0.019
Sex × education	0.028	0.233
Age × sex × education	− 0.002	0.027

Note. Sex: 0 = men, 1 = women. R^2 = 0.018. The predictive effect of age at death also held when level, pre-terminal slope, and terminal slope were used as additional predictors for the location of the change point.

* $p < .05$,

** $p < .01$,

*** $p < .001$.