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Health Sensitivity: Age Differences in the Within-person Coupling of Individuals' Physical Health and Well-Being

Ina Schöllgen¹, Jennifer Morack², Frank J. Infurna³, Nilam Ram^{2,4}, and Denis Gerstorf^{1,2}

¹Humboldt University, Berlin, Germany

²Pennsylvania State University, University Park, USA

³Arizona State University, Tempe, USA

⁴German Institute for Economic Research, Berlin, Germany

Abstract

Well-being and physical health are central indicators of quality of life in old age. Research from a between-person difference perspective finds that people in better health than their peers also report higher well-being than their peers. However, we know very little about whether changes in one domain are accompanied by changes in the other domain, particularly at the within-person level. In the present study, we introduce the construct of health sensitivity, i.e., how susceptible an individuals' well-being is to changes in physical health. In doing so, we used nine-wave longitudinal data covering 17 years from the Health and Retirement Study ($N = 21,689$; 50-109 year olds; 55% women) and applied multi-level modeling to examine the covariation of central indicators of well-being (depressive affect) and health (functional limitations) simultaneously at both the between-person and within-person level. At the within-person level, we found evidence of health sensitivity – on occasions when a typical person experienced more functional limitations than usual, he or she also reported more depressive affect –, and that health sensitivity decreased with age. Survival analysis revealed that health sensitivity was related to mortality hazards, controlling for mean levels of health and well-being. We discuss the theoretical importance of examining within-person associations between health and well-being and consider practical implications.

Keywords

well-being; functional limitations; between-person and within-person associations; mortality; aging

To address theoretically derived predictions about links between physical health and well-being at the individual level, the present study examines long-term within-person associations, introducing the construct *health sensitivity*, defined as how susceptible an individual's well-being is to occasion-specific deviations in physical health. We use

Address correspondence regarding this manuscript to: Ina Schöllgen, Federal Institute for Occupational Safety and Health (BAuA), Division 3 Work and Health, Noeldnerstr. 40/42, 10317 Berlin, Germany, schoellgen.ina@baua.bund.de.

Ina Schöllgen is now at the Federal Institute for Occupational Safety and Health (BAuA).

multilevel models and longitudinal data from the Health and Retirement Study (HRS) to simultaneously examine between-person and within-person covariation of functional limitations and depressive affect. We also examine whether key sociodemographic factors (age, gender, education) and volunteering moderate health sensitivity and explore functional implications (mortality hazards) arising from whether people are more or less health sensitive.

Physical Health and Well-Being in Old Age

Theory and research have established close associations between physical health and well-being (Lawton, 1983). For example, the disability hypothesis maintains that physical disease and disability affect emotional well-being via psychological (loss of perceived control and self-esteem), social (social isolation), and material (loss of financial resources) pathways (Watson & Pennebaker, 1989). The activity restriction model of depressed affect implies that health-related stressors lead to activity restriction, which in turn increases depressive affect (Williamson, 1998). The Strengths and Vulnerabilities Integration (SAVI) model (Charles, 2010) suggests that aging-related vulnerabilities, such as exposure to uncontrollable stressors associated with chronic health conditions and functional limitations, undermine the accumulated experience and skills that older adults use to maintain affective well-being.

A myriad of empirical reports indicate sizeable correlations between indicators of health and well-being (for overview, see Diener & Chan, 2011; Smith et al., 2002). In particular, (bidirectional) associations between functional limitations and depressive symptoms have been well-documented (Aneshensel et al., 1984; Bruce, 2001; Ormel et al., 2002). Important for the purpose of the present study is that all these reports were derived from a between-person differences perspective. For example, correlated changes suggest that participants who experience stronger declines in health than their peers also tend to report stronger declines in well-being than their peers (Hoppmann, Gerstorf, & Hibbert, 2011; Taylor & Lynch, 2004).

A Within-Person Perspective

Despite considerable insights gained from study of between-person differences, the noted associations do not allow for inferences regarding how two domains of functioning are linked at the individual level. Influential work by Molenaar (2004) and others (Curran & Bauer, 2011; Sliwinski, Hoffman, & Hofer, 2010) suggests that results from aggregated between-person analyses typically cannot be generalized to within-person associations (see Ram & Gerstorf, 2009). Associations at between-person and within-person levels might differ regarding their nature (Thorvaldsson et al., 2012) or direction (Haapanen et al., 1997; Schwartz & Stone, 1998). For example, associations between health and well-being are often stronger for trait positive affect and health than state positive affect and health (Cohen & Pressman, 2006), suggesting that separating within-person from between-person associations may reveal a slightly different and complementary perspective. Importantly, addressing such questions can help to provide direct empirical evidence for theoretical models implying that changes in health and well-being are coupled within a given individual (Charles, 2010; Williamson, 1998).

Micro-longitudinal studies, examining fluctuations from one situation or one day to the next, offer one approach for disentangling between-person and within-person associations and provide initial evidence that well-being is indeed susceptible to occasion-specific variations in health (Charles & Almeida, 2006). Although invoking a within-person perspective, such micro-longitudinal studies cannot capture health-related developments evolving over a longer period of time (years or decades), such as changes in functional limitations and disability. Our rationale here is to introduce the construct *health sensitivity*, referring to how vulnerable an individual's well-being is to long-term changes in health, which will be examined using macro-longitudinal data (e.g., biennial). In the current study, we have thus taken a cue from the analytical approaches used in micro-longitudinal studies (e.g., experience sampling) so as to empirically test psychological theories that have formulated predictions about change and covariation at the within-person level more directly and thoroughly.

Moderators of Health–Well-Being Associations

We assume that associations between health and well-being differ across a variety of individual characteristics. For example, health–well-being associations in younger adults are often stronger than among older adults (Piazza, Charles, & Almeida, 2007), a finding consistent with the idea that older adults have acquired expertise and skills in employing emotion regulation strategies over a lifetime of experiences (Charles, 2010) and hence are better able to deal with health-related stressors. Jang, Poon, and Martin (2004) reported a weaker association between disability and depression among 80+ years olds than among 60–69 years olds, probably due to desensitization about health problems among the very old.

The Reserve Capacity Model (Gallo & Matthews, 2003) implies that health–well-being associations differ by education, in that the low educated have fewer psychosocial resources (e.g., control beliefs and social support; Mirowsky & Ross, 2007), which in turn limits their coping ability and thus exacerbates the detrimental effect of health limitations on emotional functioning. Indeed, between-person associations of physical illnesses and negative affect are stronger among those with lower education compared to those with higher education (Schöllgen, Huxhold, & Schmiedek, 2012). Disadvantages in socioeconomic resources and limitations to accessing care (Crimmins, Kim, & Solé-Auró, 2011; Moen, 1996) may also result in women being more health sensitive than men. In contrast, it has been argued that men's well-being is more affected by functional limitations and disability than women's because dependence on others for help with daily activity contradicts cultural norms of masculinity (Caputo & Simon, 2013).

Finally, a compensatory hypothesis posits that the benefits of volunteering increase as individuals' capital (resources) decreases because volunteering provides older adults with capital and roles that offset loss of other roles (Oman, 2007). Studies examining between-person associations indeed suggest that volunteering is beneficial for those with chronic health conditions and functional limitations (Greenfield & Marks, 2007; Okun, Yeung, & Brown, 2013).

In sum, theoretical propositions and empirical findings based on a between-person perspective suggest that health–well-being associations differ by age, gender, education, and volunteering. In this study, we take this line of inquiry one step further and examine these variables as moderators of within-person health sensitivity.

Health Sensitivity and Mortality

One avenue for understanding the (mal)-adaptive nature of health sensitivity is to examine whether and how health sensitivity is related to long-term outcomes such as mortality. Research has primarily examined whether levels and/or changes in health and well-being are predictive of mortality (Keeler, Guralnik, Tian, Wallace, & Reuben, 2010; Wiest, Schüz, Webster, & Wurm, 2011). Only recently have studies started to examine the predictive utility of within-person covariation constructs. For example, recent work has found that stronger emotional reactivity (i.e., within-person association between daily stressors and emotions) was related to higher mortality risk, even after controlling for well-being (Mroczek et al., 2015). Considering that health declines may be conceived as a stressor, the degree to which an individual's well-being is coupled to changes in health might also be related to mortality risk.

The Present Study

We expand past research on health–well-being associations by examining within-person associations of health and well-being (health sensitivity), as manifest in long-term longitudinal data about functional limitations and depressive affect of adults aged 50+ from the HRS (up to 9 waves over 17 years, $N = 21,689$; 55% women). Functional limitations can be expected to shape daily-life functioning (day-to-day socializing, mobilizing, etc.) more directly than other aspects of health such as high blood pressure (Ormel et al., 1997). Consistent with conceptual models, we focus on hedonic aspects of well-being and make use of depressive affect as indicator. Our aim is not to expand the long tradition of examining questions about temporal ordering or causality, but to shift from a univariate outcome (here, well-being) to bivariate within-person associations (here, of occasion-specific deviations in functional limitations and depressive affect) that we have labeled “health sensitivity”.

Between-person and within-person associations are distinguished and separated using a multilevel modeling framework. At the between-person level, we hypothesized that individuals with fewer functional limitations would also tend to report lower depressive affect. At the within-person level, we hypothesized that, for the typical person, occasion-specific deviations in functional limitations would be systematically accompanied by changes in depressive affect. That is, the typical person would exhibit *health sensitivity*. We hypothesized that weaker health sensitivity would be associated with older age and higher education, that level of health sensitivity would differ with gender and volunteering, and that greater health sensitivity would be associated with higher mortality hazards.

Method

Participants and Procedure

Data were drawn from the HRS, a longitudinal study of US adults aged 50+ (and their partners). HRS started in 1992, with biennial follow-ups (see McArdle, Fisher, & Kadlec, 2007; Soldo, Hurd, Rodgers, & Wallace, 1997), and in 1998 was merged with the Asset and Health Dynamics among the Oldest Old (AHEAD) study that had started in 1993, with reassessments in 1995/1996. We analyze data from 21,689 participants who provided one or more waves of data on depressive affect and functional limitations (not available in HRS in 1992 and 1994) until 2010 and valid data for all correlates. On average, participants provided five observations. Although attrition between adjacent waves averaged 10%, selectivity analyses indicated that individuals who provided more longitudinal data (and hence contributed more to the within-person analyses) only marginally differed from those providing little or no longitudinal data ($R^2 < .02$ for all comparisons), thus providing confidence in the use of missing at random assumptions to pool all available data.

Measures

Depressive Affect—At each wave, depressive affect (DA) was measured as a sum score of eight items from the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). Participants indicated whether or not they experienced the following symptoms “much of the time during the past week”: feeling depressed, everything was an effort, restless sleep, was happy, felt lonely, enjoyed life, felt sad, and could not get going. After recoding, higher scores corresponded to more depressive affect (Cronbachs $\alpha = .70$ to .78). Descriptive statistics for all measures are given in Table 1.

Functional Limitations—At each wave, functional limitations were measured as a sum score of difficulty performing 10 everyday activities (0 = no; 1 = yes). Participants reported difficulty with using the phone, managing money, shopping for groceries, preparing hot meals, walking several blocks, climbing one flight of stairs, lifting or carrying over 10 lbs, picking a dime up, and pulling or pushing large objects (see Lawton & Brody, 1969). Higher scores indicated more functional limitations (FL) (Cronbachs $\alpha = .80$ to .84).

Moderators—*Average age* was calculated as the arithmetic mean of all available ages, separately for each participant. *Gender* was a dichotomous variable. *Education* was indexed by the number of years of formal schooling. Volunteering was indexed by individuals' answer (yes/no) to the question, “Have you spent any time in the past 12 months doing volunteer work for religious, educational, health-related or other charitable organizations?”, the first time they were asked (item introduced in 1998; see Infurna, Okun, & Grimm, in press).

Mortality—Date of death was obtained through the National Death Index. Of the 21,689 participants 6,235 (29%) had died by 2011.

Data Analysis

Data Preparation—In a first step, we separated our predictor variable, functional limitations, into between-person and within-person components (following Schwartz & Stone, 1998). The between-person component (*chronic FL_i*) was computed as the average of an individual's functional limitations across all waves. The within-person component (*occasion-specific FL_{ti}*) was computed at each wave as the deviation from person-specific averages. Data for 10 randomly chosen participants are depicted in Figure 1.

Multilevel Analysis—Multilevel models were used to separate and simultaneously examine between-person and within-person associations (for person *i* across times *t*) of depressive affect and functional limitations (Bolger & Laurenceau, 2013). The full model was specified as

$$\text{Depressive_Affect}_{ti} = \pi_{0i} + \pi_{1i}(\text{time}_{ti}) + \pi_{2i}(\text{time}_{ti}^2) + \pi_{3i}(\text{occasion-specific FL}_{ti}) + e_{ti} \quad (1)$$

$$\pi_{0i} = \gamma_{00} + \gamma_{01}(\text{chronic FL}_i) + \gamma_{02}(\text{average age}_i) + \gamma_{03}(\text{gender}_i) + \gamma_{04}(\text{education}_i) + \gamma_{05}(\text{volunteering}_i) + u_{0i}$$

(2)

$$\pi_{1i} = \gamma_{10} + \gamma_{11}(\text{average age}_i) + \gamma_{12}(\text{gender}_i) + \gamma_{13}(\text{education}_i) + \gamma_{14}(\text{volunteering}_i) + u_{1i} \quad (3)$$

$$\pi_{2i} = \gamma_{20} + u_{2i} \quad (4)$$

$$\pi_{3i} = \gamma_{30} + \gamma_{31}(\text{chronic FL}_i) + \gamma_{32}(\text{average age}_i) + \gamma_{33}(\text{gender}_i) + \gamma_{34}(\text{education}_i) + \gamma_{35}(\text{volunteering}_i) + u_{3i}$$

(5)

where π_{3i} is the operationalization of health sensitivity. Residuals are assumed to be distributed in standard ways (iid, multivariate normal). Time-in-study was centered at the mean of an individual's time series¹. Average age was centered at 69 years, and gender, education and volunteering were centered at sample means. Models were estimated using

¹Using time-in-study as the time metric allows for greater precision for the within-person analyses (because rate of change is estimated over a common time frame) and accommodation of the relatively extreme (to the length of the study) age heterogeneity of the sample (i.e., 50 to 109 years in HRS). However, because age and time-in-study are perfectly correlated within-persons, within-person changes in age are represented at level-1. The between-person differences in age (i.e., that some people are older than others)

SAS PROC MIXED (Littell et al., 2006), with full information maximum likelihood estimation, thereby treating incomplete data as missing at random (Little & Rubin, 1987) and adjusting for unbalanced data (Singer & Willett, 2003).

Survival Analysis—To examine how *health sensitivity* was related to mortality, the individual differences in health sensitivity (Bayes empirical estimates of u_{3i} from a reduced model without moderators) were output and entered into a proportional hazards model (Cox, 1972) of the form

$$h(t;x)_i = h_0(t) \exp(\beta_1 \text{health sensitivity}_i + \beta_2 \text{mean FL}_i + \beta_3 \text{mean DA}_i + \beta_4 \text{gender}_i + \beta_5 \text{education}_i + \beta_6 \text{average age}_i + \beta_7 \text{volunteering}_i) \quad (6)$$

Survival analysis was also estimated in SAS (excluding five outliers for $n=21,684$). Health sensitivity, mean FL, and mean DA were z-standardized ($M=0$, $SD=1$) so that hazard ratios refer to differences in mortality hazard associated with a 1 *SD* difference in these predictors. Other predictors were grand mean centered.

Given the large sample, we used a significance level of $\alpha < .01$ for all analyses. To evaluate effect size, we rescaled the multilevel model estimates into “standardized” regression estimates (STEs) using the relevant between-person and within-person *SDs*. Highlighting that within-person and between-person standardized effects cannot be directly compared because effects scaled in between-person *SDs* may have different implications for outcomes than effects scaled in within-person *SDs* (see discussion in Hülür et al., 2014), we set benchmarks of between-person STE = .050 and within-person STE = .010 as values to be equaled or exceeded for a regression effect to be practically meaningful.

Results

Parameter estimates from the full multilevel model used to examine health sensitivity are reported in Table 2. We present findings on between-person and within-person associations of functional limitations with depressive affect in turn.

Between-Person and Within-Person Associations of Functional Limitations and Depressive Affect

As expected, participants with more functional limitations reported more depressive affect ($\gamma_{01} = 0.445$, STE = 0.559), indicating that an individual +1.00 between-person *SD* above the sample mean in functional limitations was, on average, +0.559 *SD* above the sample mean in depressive affect (see Figure 2, upper Panel).

are represented in our average age variable that we consider at level-2. Follow-up analyses using age rather than time-in-study as the time metric (i.e., age as time-varying) yielded substantively identical results as reported here. In these analyses, we also included the interaction of age_{*it*} and occasion-specific functional limitations, hence examining moderation using age at each time of measurement rather than average age. Results revealed that health sensitivity was indeed weaker at higher (i.e., increasing) ages ($\gamma = -0.002$, $SE = 0.000$, $p < .01$) – a set of findings that are in line with the time-in-study model where average age was used as the moderator

Importantly, we found evidence for health sensitivity, with a positive within-person association of occasion-specific functional limitations and depressive affect (see Figure 2, lower Panel). For the typical person, when functional limitations were 1 within-person *SD* higher than usual, depressive affect was about 14% of a within-person *SD* higher than usual ($\gamma_{30} = 0.169$, $STE = 0.141$). However, there were substantial between-person differences in health sensitivity. As shown in Figure 3, within-person couplings of functional limitations and depressive affect are strong for some people, but weak for others. Older age was associated with weaker health sensitivity ($\gamma_{32} = -0.002$, $STE = -0.016$). No differences in health sensitivity according to gender, education, volunteering, and level of chronic functional limitations were found.

Health Sensitivity and Mortality

Results of proportional hazards models are shown in Table 3. As can be seen, health sensitivity was associated with mortality ($HR = 1.076$), controlling for average functional limitations and depressive affect and the covariates. One standard deviation difference in health sensitivity was associated with an almost 8% elevated risk of death (see Figure 4).

Follow-up analyses revealed that proportionality assumptions for health sensitivity held (no interactions between health sensitivity and time), suggesting that effects were consistent across the study period. Interactions with time were significant for all other predictors, but their inclusion did not change the substantive pattern of results. To account for the dependence of observations among couple participants, we reran the multilevel and survival analyses using random-split halves of couple participants and again obtained a substantively unaltered pattern of findings.

Discussion

The present study introduced the construct of *health sensitivity*, defined as the intraindividual covariation of physical health and well-being. Using up to 17-year longitudinal data of 50+ years olds in the HRS, we demonstrated that, at the between-person level, individuals reporting more functional limitations also report higher depressive affect. At the within-person level, we found evidence for *health sensitivity*. On occasions when participants reported more functional limitations, they also, on average, reported more depressive affect. Older individuals had weaker health sensitivity. Survival analyses showed that stronger health sensitivity is associated with higher mortality risk.

Health Sensitivity of Older Adults

Our results at the between-person level corroborate previous reports of health–well-being associations in later life (Kunzmann et al., 2000; Taylor & Lynch, 2004). Our study moved one step further and directly examined such associations at the within-person level. Such health sensitivity indicates how longer-term changes in physical health and well-being are coupled at the individual level. For the typical participant, ups and downs in functional limitations from one occasion to the next were significantly coupled with ups and downs in depressive affect. Effect size estimates suggest that both between-person and within-person associations can be considered practically meaningful, although a direct comparison is not

possible because effects are scaled in different units (between-person *SDs* vs. within-person *SDs*). Taking this into account, it would not be justified to conclude that chronic functional limitations have much larger effects on depressive symptoms than occasion-specific fluctuations.

In contrast to between-person results, *health sensitivity* findings provide direct empirical evidence for theoretical models (Watson & Pennebaker, 1989; Williamson, 1998), which predict that changes in health map onto changes in well-being, particularly when one looks at a given individual. For example, strains associated with health losses may overwhelm the emotion regulation strategies that older adults typically have available and so prompt well-being declines (Charles, 2010). It was not possible to investigate underlying mechanisms (e.g., loss of psychological, social, and material resources, activity restriction, and impaired emotion regulation), but our findings provide direct support for the assumption that health and well-being are linked within an individual.

Between-Person Differences

We found substantial between-person differences in health sensitivity, with some individuals having weaker couplings than others. Older age emerged as being associated with weaker health sensitivity, and this effect did not level off in very old age (as indicated by a non-significant moderator effect of age²). Given that losses in the health domain accumulate late in life (Smith et al., 2002) and that uncontrollable stressors associated with chronic health conditions and functional limitations often increasingly undermine the application of well-practiced strategies to effectively maintain well-being (Charles, 2010), this might seem surprising. However, we note that the average level of functional limitations in our sample was rather modest, with only few participants having experienced severe limitations.

Lower educated individuals had been assumed to be more health sensitive. We argued that their supposedly limited psychosocial resources (e.g., control beliefs, social support; Gallo & Matthews, 2003) limit their ability to cope with health-related stressors, thus exacerbating its detrimental effect on emotional functioning. Although higher educated individuals showed a tendency to be less health sensitive, this effect was not practically meaningful. Likewise, gender differences in health sensitivity also failed to reach our criterion of practical significance. Prior studies from a between-person perspective provided some evidence for differences in health-well-being links by gender and education (Caputo & Simon, 2013; Schöllgen et al., 2012). Our findings of non-significant moderator effects of education and gender on the within-person covariation of health and well-being reveal a different picture.

We had also expected that volunteering reduces health sensitivity because volunteering has been shown to be important for quality of life when personal resources decrease (Oman, 2007). This assumption was not supported by our results. We acknowledge though that we used a rather broad measure of volunteering, not distinguishing different types of volunteering (but see Greenfield & Marks, 2007). Moreover, volunteering is only one aspect of social participation. For example, informal social activity (with friends and relatives) and social orientation are known to be relevant for well-being and health, particularly late in life (Gerstorf et al., 2016). It would thus be instrumental to further pinpoint how particular

aspects of social orientation may result in reduced health sensitivity, especially because our results suggest that health sensitivity is predictive of mortality hazards.

Outcomes of Health Sensitivity

Our analyses have demonstrated that individuals with higher health sensitivity have an increased likelihood of death, over and above mean levels of functional limitations and depressive affect. This suggests that health sensitivity represents a potential threat to successful aging. In line with recent propositions (Martin et al., 2015), our research links physical and psychological aspects of successful aging and shows that successful aging in terms of high well-being and longevity can be achieved even if health declines, i.e., for those individuals with lower health sensitivity. Our study has provided evidence of construct validity, showing that between-person differences in health sensitivity are linked with hard-wired outcomes. These analyses also add to existing research by moving beyond the consideration of the predictive utility of univariate intraindividual variability (e.g., in health or in well-being) to examine whether and how bivariate intraindividual covariations (here, health sensitivity) are associated with subsequent mortality hazards.

Limitations and Outlook

In closing, we note several limitations of our study. First, it is unclear if our results based on the CES-D operationalization of depressive affect generalize to other aspects of well-being, including life satisfaction or positive affect. Disparate findings of earlier studies (Kunzmann et al., 2000) suggest that quantifications of health sensitivity may depend on the well-being measures used. Similarly, because health is a multi-dimensional construct (Lawton & Lawrence, 1994), it would be intriguing to examine health sensitivity based on medical diagnoses of physical disease. Future research should also explore additional moderators of health sensitivity, including the role of personality and control beliefs, both of which are known correlates of health and well-being (Gerstorf et al., 2014; Infurna & Gerstorf, 2014). For example, optimism has been shown to be associated with better coping flexibility (Carver & Connor-Smith, 2010), and hardiness has been associated with coping strategies considered adaptive in dealing with health declines, such as support-seeking (Williams, Wiebe, & Smith, 1992). It thus seems plausible that these and other personality dimension moderate health sensitivity.

As a second limitation, our results obtained from a relatively healthy sample may not generalize to less well functioning population segments of older adults. One may argue that more severe forms of health limitations may prompt stronger reactivity in well-being. If true, then we may have underestimated health sensitivity in our overall healthy and happy sample. Third, we have applied methods to a macro-longitudinal study that are typically applied to micro-longitudinal studies with larger number and more frequent sampling of occasions. More reliable within-person estimates could be obtained from data collected more often than our (max) nine waves and with more closely spaced assessments than the two-year intervals in HRS (Mejia et al., 2014).

Finally, our primary aim was not to examine questions about temporal ordering or causality, but for conceptual reasons (and the analytical constraints inherent in multilevel models) pick

one such direction of associations and tease apart between-person associations from within-person associations. In doing so, we examined health sensitivity, operationally defined as how susceptible an individual's depressive affect is to changes in physical functioning. It is an intriguing question for future inquiry to reverse the a priori defined set-up and pick a different direction of associations. Overall, theory and previous results from a between-person perspective suggest that associations between depressive affect and functional limitations go both ways, although the timing of effects might differ (Aneshensel et al., 1984; Ormel et al., 2002). The time-scale of assessment in the HRS (2-year intervals) does not facilitate in-depth inquiry into the time course of the different feedback loops, however. Hence, the data and analyses reported here are better conceived as only implying “concurrent” associations within a 2-year time-frame.

Generally speaking, the mechanisms underlying health sensitivity need to be better understood so as to eventually implement and practice coping or adaptation strategies in interventions. For example, older adults dealing with increasing disease and functional limitations might disengage from activities involving physical fitness and try to replace the lost activities (Zimmer, Hickey, & Searle, 1997). This might, in turn, limit the effects of health decline on well-being.

To conclude, our study contributes to the literature in several ways. First, we introduced a health sensitivity construct. To our knowledge this is the first time this intraindividual covariation construct has been articulated and examined in longitudinal panel data. This allows for more directly testing theoretical assumptions on links between health and well-being at the individual level and addressing concerns regarding inferences from the aggregate level to the individual level. Using an expanded multilevel model, we found evidence for health sensitivity, i.e., on a given occasion when an individual experiences health losses, a corresponding well-being decline occurs. Second, our results point to substantial between-person differences in health sensitivity, indicating the need to further explore potential moderators. As a final major contribution, our study shows that health sensitivity at the individual level constitutes a risk factor for mortality, demonstrating evidence for the validity of the health sensitivity construct. Our study provides further impetus for research exploring potentially underlying pathways and inquiry into ways to modify health sensitivity in older adults.

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Figure 1.

Individual average (top panel, 1A) and residual (bottom panel, 1B) functional limitations for 10 participants. The numbers 1-10 on the plots correspond to the ID of the participants. Functional limitations scores from 10 participants were used to illustrate how stability and change of the variables can be separated into a between person component (individual average) and within-person component (individual residual). Individual averages were obtained by taking the mean across an individual's time series and are therefore static. Individual residuals represent a deviation from each participant's individual average across the entire time series. Residuals were centered at zero, and negative residuals indicate that a participant reported fewer functional limitations than his or her average.

Figure 2.

The top panel (2A) depicts the average between-person association of depressive affect and functional limitations. The dots are raw data from 1,000 participants, and the line shows the average association between individuals' average depressive affect and functional limitations. Participants who reported more depressive affect also experienced more functional limitations on average. The bottom panel (2B) shows the average within-person relationship of the variables. On occasions when individuals reported more depressive affect than usual, then they also reported more functional limitations than usual. The within-person relationships of 10 participants are also plotted.

Figure 3.

Individual plots of intraindividual covariation between depressive affect (solid line) and functional limitations (dashed line). Each plot represents an individual participant. The top panel (3A) illustrates a person with a positive, strong within-person association (strong health sensitivity) indicating closely related depressive affect and functional limitations trajectories. In contrast, the bottom panel (3B) shows a person with no within-person association (i.e., no health sensitivity) between the variables.

Figure 4.

Illustration of the predictive effect of health sensitivity for survival over up to 19 years among participants in the Health and Retirement Study. Stronger health sensitivity was associated with a higher risk for mortality. The graph shows survival curves for the lowest quartile (solid line) and the highest quartile (dashed line) of health sensitivity.

Table 1
Descriptive Statistics and Intercorrelations of Study Measures

Measure	<i>M</i>	<i>SD</i>	1	2	3	4	5	6
Depressive affect <i>T</i> ₁ (0-8)	1.37	(1.88)	--					
Functional limitations <i>T</i> ₁ (0-10)	1.19	(1.70)	.42*	--				
Age <i>T</i> ₁ (50-104)	63.82	(9.46)	-.01	.15*	--			
Gender (0 = men, 1 = women)	0.55	(0.50)	.09*	.13*	.04*	--		
Education (0-17)	12.15	(3.35)	-.24*	-.25*	-.21*	-.06*	--	
Volunteering (0=no, 1=yes)	0.32	(0.47)	-.15*	-.16*	-.08*	.01	.24*	--

Note. *N* = 21,689.

* $p < .01$.

M = mean. *SD* = standard deviation.

Table 2
Multilevel Model Results for Examination of Health Sensitivity and Moderators

Parameter	Estimate (SE)	STE
<i>Fixed Effects</i>		
Intercept γ_{00}	1.519 [*] (0.009)	
Changes over time-in-study and moderating correlates		
Time γ_{10}	0.027 [*] (0.001)	0.081 [*]
Time ² γ_{20}	0.002 [*] (0.000)	0.026 [*]
Average age γ_{02}	-0.027 [*] (0.001)	-0.191 [*]
Gender γ_{03} (0 = men, 1 = women)	0.134 [*] (0.017)	0.049
Education γ_{04}	-0.065 [*] (0.002)	-0.160 [*]
Volunteering γ_{05} (0=no, 1=yes)	-0.197 [*] (0.018)	-0.068 [*]
Average age $\times$ time γ_{11}	0.001 [*] (0.001)	0.029
Gender $\times$ time γ_{12}	-0.006 [*] (0.002)	-0.009
Education $\times$ time γ_{13}	0.003 [*] (0.000)	0.030
Volunteering $\times$ time γ_{14}	0.004 (0.002)	0.006
Between-person and within-person associations		
Chronic FL γ γ_{01}	0.445 [*] (0.005)	0.559 [*]
Occasion-specific FL γ_{30}	0.169 [*] (0.005)	0.141 [*]
Moderators of within-person association		
Occasion-specific FL $\times$ chronic FL γ_{31}	0.004 (0.003)	0.006
Occasion-specific FL $\times$ average age γ_{32}	-0.002 [*] (0.000)	-0.016 [*]
Occasion-specific FL $\times$ gender γ_{33}	-0.020 (0.009)	-0.008
Occasion-specific FL $\times$ education γ_{34}	-0.003 (0.001)	-0.008
Occasion-specific FL $\times$ volunteering γ_{35}	-0.008 (0.010)	-0.003
<i>Random effects</i>		
Variance intercept σ_{u0}^2	1.408 [*] (0.019)	
Variance occasion-specific FL σ_{u3}^2	0.068 [*] (0.003)	
Variance time σ_{u1}^2	0.003 [*] (0.000)	
Variance time ² σ_{u2}^2	< 0.001 [*] (0.000)	
Covariance intercept, occasion-specific FL $\sigma_{u0,u3}$	0.066 [*] (0.006)	
Covariance intercept, time $\sigma_{u0,u1}$	-0.003 (0.001)	
Covariance intercept, time ² $\sigma_{u0,u2}$	-0.009 [*] (0.000)	
Covariance occasion-specific FL, time $\sigma_{u3,u1}$	-0.001 (0.001)	
Covariance occasion-specific FL, time $\times$ time $\sigma_{u3,u2}$	< -0.001 (0.000)	
Covariance time, time ² $\sigma_{u1,u2}$	< -0.001 [*] (0.000)	
Residual variance σ_e^2	1.563 [*] (0.008)	
-2LL	436,091	

Parameter	Estimate (SE)	STE
<i>AIC</i>	436,113	

Note. $N = 21,689$.

* $p < .01$, or STE = 0.050 for between-person STE, and STE = 0.010 for within-person associations.

FL = functional limitations. STE = standardized regression estimate. Age is centered at 69 years.

Table 3
Proportional Hazards Regression Results for Health Sensitivity Predicting Mortality

Predictor	HR (95% CI)
Health sensitivity	1.076 [*] (1.052-1.102)
Mean (chronic) functional limitations	1.492 [*] (1.451-1.534)
Mean depressive affect	0.986 (0.955-1.018)
Average age	1.052 [*] (1.049-1.055)
Gender (0 = men, 1 = women)	0.658 [*] (0.626-0.693)
Education	0.997 (0.989-1.004)
Volunteering (0 = no, 1 = yes)	0.805 [*] (0.758-0.855)

Note. $N = 21,684$.

^{*} $p < .01$.

HR = hazards ratio. CI = confidence interval.