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Time-to-death patterns in markers of age and dependency

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Abstract

We aim to determine the extent to which variables commonly used to describe health, well-being, and disability in old-age vary primarily as a function of years lived (age), years left, or as a function of both. We analyze data from the US Health and Retirement Study to estimate chronological age and time-to-death patterns in 60 such variables. We describe results for individuals with 15 or fewer remaining years of life, after age 70 and whose completed lifespans do not exceed 100. Our results show that most markers used to study well-being in old-age vary along both time dimensions, but that variation over remaining years of life is typically much stronger for the age-ranges and variables examined.

1 Background

Some individual life transitions are probably best described as a function of time since birth (chronological age), while others are probably best described as a function of time until death (thanatological age). These two ways of measuring age are different in the aggregate because lifespans vary between individuals. Recently, we presented some results of transforming data classified by chronological age, like census population counts, into thanatological age using some simple lifetable assumptions[1]. This transformation yields the thanatological

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[1]A paper on this topic is currently under review (**?**). **??** had already done the same thing some 30 years earlier, and we understand that S. Scherbov also unwittingly produced the same result over a decade ago. It is safe to say that most demographers are still unaware of the method, however.

age structure of the population under a particular set of mortality assumptions. However, such lifetable-based transformations are idealized, and in many informal conversations the question has been raised as to which life transitions may actually be better understood as a function of thanatological age rather than chronological age.

Work has been done on this topic in other domains, and topics examined can be roughly categorized into two types: 1) things that are a function of apparent or perceived time to death (**????**), and 2) things that are a function of actual time to death (**??**). The former are mostly studies on cognitive transitions and economic behaviors, while the latter are mostly studies on health expenditure. In this paper we will expand the latter group, focusing on a broad range of questions from the US Health and Retirement Study (**?**), which at present provides a fairly good sample from which to aggregate results for the final 15 years of life.

The present study is exploratory. We have the impression that such patterns are mostly novel to demographers and as-yet unincorporated in population-level indicators of ageing or disability. We aim to identify a range of domains in which it makes sense to think from a thanatological perspective. In the following sections we describe our approach to this exercise.

In short, for a given characteristic, we produce a demographic surface, where chronological age and thanatological age are the primary x and y axes, respectively. We then characterize this surface in a simple way by determining the average direction of steepest ascent on the surface, which tells us the primary direction of variation. If something varies more along the thanatological axis, then we call it a thanatological characteristic, and so forth. In practice, we derive the degree to which a characteristic is thanatological as a percentage. Some preliminary results are reported in tables below, and surface plots are made available. In the complete paper we will present a more structured survey and a distilled set of comparisons that we hope will stir thought on this topic.

2 Data & Method

All findings reported in this paper are based on data from the US Health and Retirement Study (HRS). We use the Rand edition of the data, which is conveniently merged across all ten waves, and we calculate thanatological age based on date of death information in the mortality followup module. We restrict the sample to only those individuals that have died, which reduces the dataset from 36986 individuals with an average of 5 interviews each to 11947 deceased individuals with an average of 4.25 interviews each. Further winowing from our weighting criterion reduces the dataset to 11520 individuals with 4.1 interviews each on average. Person-weighting is described in the following section. In the present exploration, we do not examine within-individual variation, and each instance of an interview is treated as an independent observation.

2.1 Weighting

Person weights are needed in order to estimate population-level means. One difficulty with the HRS is that the institutionalized population is treated as a second target population. In all waves but 5 and 6, there are no person weights assigned to institutionalized individuals. In some cases we try to fill the gap according to some simple assumptions. If the individual was assigned a weight in a previous wave, we carry this weight over as a constant, unless there was also a non-zero weight in a future interview, in which case we assign the weight according to the within-individual linear pattern. Some individuals are in the dataset, but are excluded (spouses mostly) for not having reached age 61. In these cases, we discard interviews with no person weights at young ages.

2.2 Age

Thanatological age is calculated for each individual as the lag between interview and death dates expressed as decimal years. Chronological age is calculated as the lag between birth and interview date in decimal years. Birth dates and death dates in the original data are typically rounded up to the end of the month, but this is more than enough precision for our purposes. Since we are interested in comparing characteristics over both chronological age and thanatological age simultaneously, we are interested in having estimates over a good spread of both age perspectives. Figure 1 shows the case count in two-year age groups over the range of ages that are in the data and included for this study (yellow bin). Darker blues indicate higher case counts, and the contours approximate counts at this level of aggregation. In practice, these counts are a maximum, since particular variables studied may be missing.

Note that Figure 1 resembles a Lexis surface in some ways, but it is not organized by years or birth cohorts. Instead, years and birth cohorts in the data are overlapped and treated as a single period and a single birth cohort. We limit the study area to chronological ages 70 and higher, and thanatological ages 15 and lower, such that the sum of the two ages does not exceed 100. These bounds allow for reasonably stable estimates of surfaces for the studied characteristics. We cut off below chronological age 70 in order to remove some patterns that appear to be due to retirement rather than senescence processes, and also to avoid some potential compositional bias, as these are the typical ages of recruitment for the HRS.[2]

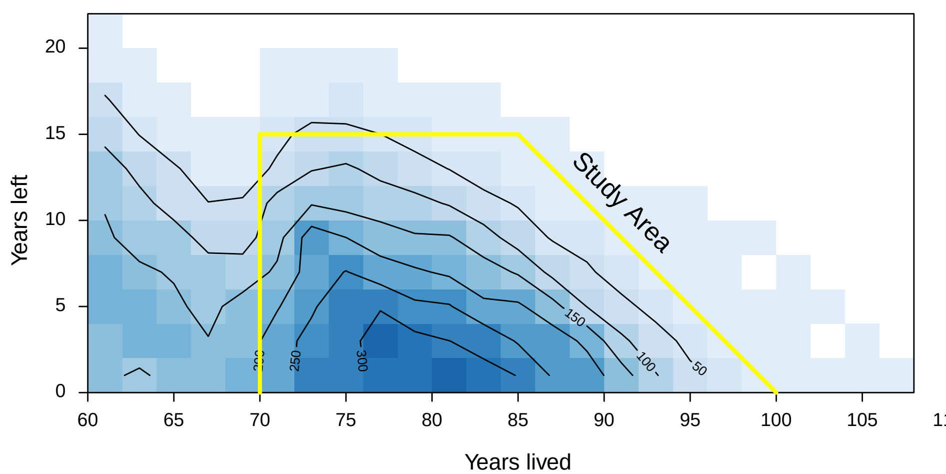
2.3 Variables

We aim for a broad overview of the age variation across different dimensions of old-age disability and well-being. For this reason we select a wide variety of questions from the HRS data to describe here. These include questions grouped

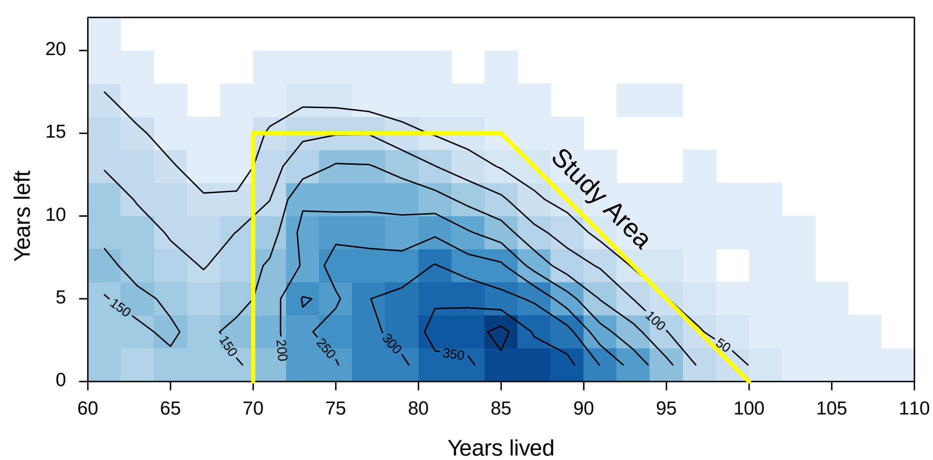
[2] Conceivably, the study area could be expanded after the addition of future mortality follow-ups.

Figure 1: Case counts in two-year age bins. Chronological age (Years lived) on the x axis and thanatological age (Years lives) on the y axis. Darker blues indicate higher case counts.

(a) Males



(b) Females



roughly into the following categories: Activities of daily living (ADL), instrumental activities of daily living (IADL), measures of healthcare utilization, functional and chronic conditions, psychological measures, and health behaviors. In all, we report summary results from 60 individual items.

We judge the degree of chronological versus thanatological age variation by creating surfaces over both age dimensions, and for this each survey question was required in a format suitable for numeric operations. This requires some compromises in data quality, since some coded responses are less directly quantifiable, and our conversions were at times ad-hoc. The treatment of individual variables will be described in an appendix in a future revision of this paper.

2.4 Loess smoothing

Direct tabulations of the weighted data are possible, and usually not too noisy, but surface legibility is enhanced by estimating based on a loess-smoothed surface. For each variable of interest, we convert values to a numeric scale. For variables where a numeric scale is not the natural form of observation, we describe the conversion protocol in an appendix[3]. We then fit a two-dimensional loess model[4] to the weighted individual-level data for each sex separately, where the numeric characteristic value is the dependant variable and individual decimal values of thanatological and chronological age are the independent variables. Weighting is then explicit by person-weights, and implicit by point density within the surface. All individuals are included in the model fit, but point predictions are calculated for a grid of single thanatological and chronological ages within the study area outlined in Figure 1 and described in the previous section.

2.5 Finding the fall-line

The model fit for each variable is used to produce a contour surface, which can be interpreted visually. In most situations it is obvious to the eye whether a variable operates over thanatological age or over chronological age, but there are also some instances where both are at play, the pattern is evidently distorted by underlying cohort heterogeneity, or where the relationship is unclear. An example surface for self-reported health (SRH) is shown in Figure 2.

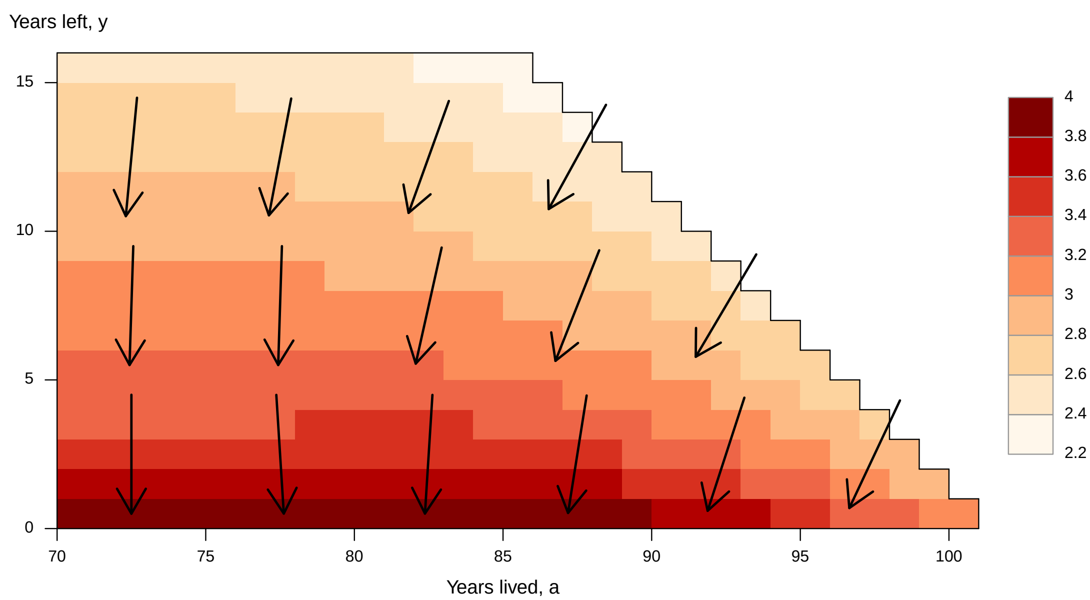
In the case of Figure 2 note that there is regular variation in the direction of both axes, but that the variation over thanatological age (y axis) is sharper, i.e., it implies a steeper climb than does the apparent decrease over chronological age.

In order to characterize this surface, we find the direction of steepest ascent for a regular grid of points. These directions are shown with arrows in Figure 2. If the direction is exactly 90° or 270°, then we know that the process is essentially a thanatological one, at least in the age-range studied. If the direction is 0° or 180°, then the characteristic can be said to be chronological. In our experience, most variables that we might be interested in are functions of both kinds of age, and so to determine the primary source of variation, we take the slope-weighted mean of each arrow direction, translate this to the upper-right

[3]Variable appendix not included in proposal.

[4]We fit using the `loess()` function in base `R` (??) and its related prediction method. The smoothing parameter, `spar`, is set to 0.5.

Figure 2: Mean male SRH by years lived (x axis) and years left (y axis).



unit quadrant, and then translate to a percent scale, where 90° is 100% thanatological and 0° is 100% chronological. For example, we judge SRH for males (Figure 2) to be %85.4 thanatological. However, around age 70-75, it is nearly %100 thanatological.

Some variables display complex surfaces, and may operate in different ways depending on particular age coordinates. In these cases, the result of the above procedure is too simple, and for this reason we provide the surface plots in supplementary online material.[5]

3 Results

This section contains the distilled results for each sex-variable surface. In each case we only report the average direction of steepest ascent, which tells us the degree to which variation is primarily over thanatological age or over chronological age. We do not display the strength of the relationship.[6] A future revision will include detailed discussion of the results. For now, we report that most variables studied vary much more over thanatological age than over chronolog-

[5]Plots are for each sex separately, and have been compiled into two multipage pdf documents, each containing all variables for one sex. Links have been shortened. Males: `http://goo.gl/pzEHHk`, Females: `http://goo.gl/xyBMxO`.

[6]Variables operate on different scales, and we are still thinking of how best to report slopes for the purpose of making comparisons.

ical age, at least for the age-ranges studied. The consistency of this finding is much greater than we expected, but it is not universal.

Results for males and females are color-coded with a thermometer scale in order to facilitate skimming the tables: dark red indicates predominantly thanatological variation and dark blue indicates predominantly chronological variation.

The most chronological variation in the data we examined are current and ever smoking, body mass index (BMI) and having had outpatient surgery in the past 24 months. Most other variables are very strongly thanatological. We do not at the time of this writing have an explanation for why smoking is not more thanatolgical in nature, but one possibility is uncontrolled compositional distortion in the underlying data. This could be so if younger respondents are, on average, from later waves and older respondents are, on average, from earlier waves, in which case strong birth cohort effects could carry through into this otherwise *timeless* age-surface. We will test for this possibility in a future revision, and in this case we will make the same control for all variables. The strength and consistency of the thanatological patterns obtained at this time is nonetheless striking and appears worthy of more careful investigation.

3.1 ADL

Question	Male % Thano	Female % Thano
Diff. walking across room	% 86.0	% 85.8
Diff. dressing	% 88.5	% 88.6
Diff. bathing/showering	% 82.0	% 86.5
Diff. eating	% 91.3	% 92.3
Diff. getting in/out bed	% 93.3	% 91.3
Diff. using toilet	% 88.0	% 90.4

3.2 IADL

Question	Male % Thano	Female % Thano
IADL 3-point	% 86.8	% 84.6
IADL 5-point	% 85.6	% 85.8
Health limits work	% 92.9	% 91.4
Diff. using map	% 83.8	% 76.2
Diff. using telephone	% 78.2	% 83.6
Diff. managing money	% 87.5	% 82.7
Diff. taking meds	% 90.6	% 85.2
Diff. shopping for groceries	% 79.9	% 80.7
Diff. preparing hot meals	% 86.3	% 86.8

3.3 Chronic conditions

Question	Male % Thano	Female % Thano
High blood pressure, ever	% 74.2	% 78.9
Diabetes, ever	% 66.4	% 66.8
Cancer, ever	% 88.8	% 86.5
Lung disease	% 80.0	% 76.0
Heart problems, ever	% 79.5	% 90.2
Stroke, ever	% 81.9	% 89.0
Arthritis, ever	% 82.2	% 92.8
Nr chronic conditions	% 84.5	% 90.4

3.4 Functional limitations

Question	Male % Thano	Female % Thano
BMI	% 56.6	% 46.3
Back problems	% 83.1	% 83.8
Mobility difficulty index	% 91.0	% 90.7
Large muscle difficulty index	% 91.9	% 94.2
Gross motor difficulty index	% 89.2	% 88.6
Fine motor difficulty index	% 88.4	% 91.2

3.5 Behaviors

Question	Male % Thano	Female % Thano
Alcohol, ever	% 87.3	% 85.9
Alcohol nr of days / week	% 75.8	% 79.8
Alcohol nr drinks per drinking day	% 64.1	% 69.5
Ever Smoker	% 49.8	% 41.5
Current Smoker	% 35.2	% 21.5

3.6 Psychological factors

Question	Male % Thano	Female % Thano
Depression score	% 90.9	% 92.6
Self-reported health	% 85.4	% 90.9
Psych problems , ever	% 90.4	% 87.4
Felt Depressed	% 89.0	% 90.1
Everything an effort	% 93.1	% 90.9
Sleep restless	% 88.4	% 80.0
Was happy	% 81.4	% 85.0
Felt lonely	% 61.4	% 87.4
Felt sad	% 90.9	% 87.1
Couldnot get going	% 92.3	% 94.3
Enjoyed life	% 73.2	% 91.3

3.7 Healthcare utilization

Question	Male % Thano	Female % Thano
Overnight hospital: 24 mo	% 94.0	% 94.6
Nr hospital stays: 24 mo	% 94.6	% 93.0
Number nights in hospital: 24 mo	% 95.2	% 91.0
Overnight stay nursing home: 24 mo	% 90.0	% 89.5
Nr nursing home stays: 24 mo	% 89.3	% 90.6
Nr nights nursing home: 24 mo	% 85.1	% 85.0
Nursing home at interview	% 88.5	% 88.6
Dr visit: 24 mo	% 68.6	% 70.6
Number Dr visits: 24 mo	% 94.0	% 89.5
Home health care: 24 mo	% 93.9	% 91.2
Prescription drugs regularly: 24 mo	% 78.8	% 77.3
Outpatient surgery: 24 mo	% 46.7	% 47.5
Dental visit: 24 mo	% 67.8	% 68.0
Special health fac visit: 24 mo	% 74.4	% 85.1
Imputed total medical expend.	% 96.5	% 95.3