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LIVING ALONE AND SUBSEQUENT LIVING ARRANGEMENT TRANSITIONS AMONG OLDER AMERICANS

A Dissertation Presented

by

YAO-CHI SHIH

Submitted to the Office of Graduate Studies,
University of Massachusetts Boston,
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 2016

Gerontology Program

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AMONG OLDER AMERICANS

A Dissertation Presented

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ABSTRACT

LIVING ALONE AND SUBSEQUENT LIVING ARRANGEMENT TRANSITIONS AMONG OLDER AMERICANS

May 2016

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Past research often considers living alone as a risk factor for older persons. In fact, adverse health outcomes are associated with living arrangement transitions, suggesting a need to consider the dynamic process of living arrangements. Using eight waves of the Health and Retirement Study (1998-2012), this study examines three research questions: (1) Do older Americans' living arrangements exhibit a pattern of sequence? (2) What are implications of living arrangements at particular older ages on life expectancy? (3) What factors predict transitions out of a living alone arrangement?

The first analysis displays and classifies ordered patterns of living arrangements over time. Baseline living arrangements have a substantial influence on subsequent transitions. Major patterns of women's living arrangement sequences are more diverse than those for men. In particular, living alone is both the major living arrangements at

baseline or intermediately after baseline. These results suggest the importance of the living arrangement status at old ages in relation to subsequent living arrangements over time.

Next, multistate life tables are estimated for calculating life expectancy in total and among distinct living arrangements. While the expected percentage of time spent living alone for men increases with age, about half of women's total life expectancy at any ages is spent living alone. Older persons living alone do not have shorter life expectancies than those in co-residential living arrangements, particularly among women. This suggests a selection process in which less robust older persons tend to transition to other living arrangements or die at younger ages.

Lastly, discrete-time event history models are used to examine factors associated with transitioning from living alone. Sentinel health events and poorer functional status are associated with an increased risk of death, and, to a lesser extent, a subsequent transition to co-residence or institutionalization. Analyses of transitions from living alone measured concurrently with changes in functional status suggest that many transitions may be immediate reactions to a recent health decline rather than adjustments following a progressive health decline. In either case, subsequent co-residence does not appear to be a common adaptation for many older adults who live alone with increased needs for care.

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I am deeply indebted to many people who have contributed to the completion of this dissertation. I give special thanks to Frank Porell for his steadfast guidance and support in response for my countless struggles throughout the dissertation process. To Jeff Burr and Mark Hayward I give my heartfelt thanks. Their thoughtful participation is a constant source of encouragement for me to go on. I also thank Jan Mutchler and Pamela Nadash who patiently lead me to embark on the course of social research. This accomplishment would not have been possible without the wonderful members of the Gerontology Program. For all the opportunities and support that I have been given, I am beyond grateful.

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CHAPTER 1

INTRODUCTION

Demographers have been concerned about the trend of increasing prevalence rates of living alone among older persons along with declines parent-children co-residence. Throughout the twentieth century, the percentage of widowed older persons has been increasing in the United States (Kramarow, 1995) and in several European countries (Agree and Glaser, 2009; Tomassini, Glaser, Wolf, van Groenou, & Grundy, 2004). During the same period, the rate of older parent-adult children co-residence has declined substantially (Kramarow, 1995; Ruggles, 2007), and the average years that older persons live in parent-children co-residence also decreased roughly over the later half of the twentieth century (Schoeni, 1998).

From a macro perspective, demographers attribute these trends to declines in fertility or childlessness that result in older persons having fewer, if any, children to live with (Macunovich, 1995; Schoeni, 1998), improved economic security that supports independent living (Costa, 1999; Michael, Fuchs, & Scott, 1980; Kramarow, 1995; McGrarry & Schoeni, 2000), and shifting residential preference in its broadest sense (Kramarow, 1995; Ruggles, 1996). Moreover, reductions in childhood mortality are also considered a contributing factor to increased availability of kin because children are more likely to survive to adulthood (Schoeni, 1998). Some researchers emphasized a particular

explanation, such as lower fertility rates (Macunovich, 1995) or income (McGrarry & Schoeni, 2000), while others believe that a broader change in family values (Ruggles, 1996) or social transformations (Kramarow, 1995) is major contributing factors. In historical studies, kin availability and economic independence are repeatedly cited as factors that explain the trends of living alone and co-residence among older person at the aggregate level. Although it is less clear, residential preferences or family values are also noted and measured by proxy indicators to capture the overall social change.

In the 1980s and 1990s, there was another stream of research that used either cross-sectional or longitudinal micro-level data to better understand the living arrangements of older persons and changes in them over a relatively short period of time compared to the aggregate data on historical changes. Most of this research was aimed at clarifying some myths about living alone or investigating whether changes of families with fewer children will create problems in caring for an expanding older population.

Living arrangements are representative of both causes and consequences of family structure and individual processes (Lawton, 1981; Mutchler, 1992; Richards, White, & Tsui, 1987). Any change in living arrangements cannot be exempted from the influence of both the individual and their kin. Living arrangements are often defined in the cross-sectional sense as an aggregation of individuals in a particular household unit, in that living arrangements are a snapshot of the composition of the household members at a given time (Stockmayer, 2004). The presence of household or family members will presumably facilitate exchanges in support and affection with each other on a continual basis.

Changes in living arrangements mark the departure or addition of household members for various reasons (Mutchler, 1992). Older adults' living arrangements not only indicate whom they live with but also imply social exchanges between the individual and other household members (Waite & Hughes, 1999; Hughes & Waite, 2002; Wilmoth, 2000). The direction of support among older and younger household members favors the younger members until older members reach fairly old age (Choi, 2003; Crimmins & Ingegneri, 1990; Lee & Dwyer, 1996; Spitze, Logan, & Robinson 1992; Ward, Logan, & Spitze, 1992). Thus, the significance of changes in living arrangements for older adults does not exclusively lie in the household compositional changes but in the fact that the prior exchange will be inevitably altered. In the case of living alone, older persons in this arrangement may resume or enhance social support and social relations by transitioning out of living alone to others living arrangements.

Living alone represents a unique solitary state during an older adult's life course. Older adults who live alone may have entered this arrangement due to personal choice early in their life course, or transitioned into the living alone state abruptly because of marital disruption. Currently, there are two views, either positive or negative, regarding the state of living alone. The positive view is that living alone with or without a spouse is considered an independent lifestyle that is self-sufficient and preferred by older adults (Burr & Mutchler, 2007). Empirical studies find that older persons living alone have more health and financial resources (Mutchler & Burr, 1991; Mutchler, 1992) and even have the same health profiles as those who are married (Davis, Moritz, Newhaus, Barclay, & Gee, 1997). In particular, researchers show that living alone is not equal to being alone

(Berkman, 2000). Living alone can be positively associated with vitality and mental health as long as social support is strong (Michael, Berkman, Colditz, & Kawachi, 2001).

The negative view is that relative to those living with others, living alone is considered a psychosocial risk factor or a negative household context that is directly or indirectly related to institutionalization and mortality (Davis, Neuhaus, Moritz, & Segal, 1992; Martikainen, Moustgaard, Murphy, Einiö, Koskinen, Martelin, & Noro, 2009; McCann, Donnelly, & O'Reilly, 2011; Rogers, 1996; Wolinsky, Callahan, Fitzgerald, & Johnson, 1992). However, findings about the consequences of living alone are mixed. Some find that older adults who live alone do not have a higher risk of dying, and that living with others or transitioning to living with others are associated with greater mortality risk (Davis et al., 1997). Others find that physical conditions and cognitive deficits are related to higher likelihoods of living with others or institutionalization relative to continuing to living alone (Hays, Pieper, & Purser, 2003; Worobey & Angel, 1990).

In fact, these two views about living alone may not be contradictory to each other. Living alone can be an unstable living arrangement or a disjuncture in the life course (See Mutchler & Burr, 1991). Unlike other living arrangements with multiple exiting options, the way out of living alone is most likely through institutionalization or death (Mutchler, 1992; Wilmoth, 1998). On the one hand, this unidirectional pathway of living alone may indicate older persons' behavioral patterns and personal preferences, so that they maintain this solitary living arrangement until institutionalization or death. On the other hand, the unidirectional pathway may also imply a longer-term health consequence of living alone, which can make the transition out of living alone appear to be daunting.

Many older adults start living alone sometime in later life. As they grow even older and encounter declining health or increasing long-term care needs, older adults living alone may find it harder to sustain this solitary arrangement and may face an increased risk of exiting the community-based living arrangements through institutionalization or death. Established literature has shown that timely responses to the disablement process (Verbrugge & Jette, 1994; Speare, Avery, & Lawton, 1991), making changes in living arrangements (Davis, et al., 1997; Kasper, Pezzin, & Rice, 2010), and increasing proximity to children (Silverstein, 1995; Rogerson, Burr, & Lin, 1997) can help to alleviate potential pressing effects associated with the state of living alone, such as lack of accessible emotional or instrumental support.

Organization of the Dissertation

Past research often consider living alone as either an independent life style or a risk factor for older persons. However, empirical results show that adverse health outcomes are often linked to a living arrangement transition, instead of simply living alone, suggesting a need to better consider the dynamic process of living arrangements in later life. The dissertation study approaches the dynamic processes from three perspectives. The study first explores the relation of living alone in line with other living arrangements by displaying ordered patterns of living arrangements over time. Second, assuming that those living alone continue the solitary arrangement without any transition, the study turns to examine what the long-term implications may be. Third, as older persons do change their living arrangements, the study investigates what are the forces that support or deter them from continuing living alone.

The dissertation begins with an introduction chapter describing research questions of the study, data and methodological issues, and the organization of the dissertation. The next three analytic chapters that follow are dedicated to examine the three major research questions of this dissertation:

(1) Do older Americans' living arrangements exhibit a pattern of sequence?

(2) What are implications of a living arrangement status at a particular age on life expectancy?

(3) What are the factors that predict a transition out of a living alone arrangement by older Americans?

Past research has shown that men and women face different mortality risks and have different kinship networks and interactions, which lead to distinct patterns of living arrangement transitions in later life. The three analysis chapters entail gender-specific analyses of late life living arrangement transitions.

Living Arrangement Sequences Among Older Americans

An older person's living arrangement sequence is an ordered collection of living arrangement states observed annually over time. While there is a body of research examining the prevalence of living arrangements among older persons at a point of time and the prevalence of transitions among different living arrangements between two points in time, very little is known about the sequences of living arrangements of older persons over an extended period of time. The first analysis chapter explores what are these ordered longitudinal patterns of living arrangements in later life. It also examines whether living alone is a disjuncture between living arrangements or by itself a dominating way of living. The analysis takes a model-free approach and describes raw

sequences of living arrangements by treating each observed sequence of living arrangements for an older person as a unit of analysis that reflects a unique course of life history. This chapter contains a descriptive analysis of living arrangement sequences for men and women over a fourteen year period. Sequence analysis and cluster analysis are applied to identify and classify various unique living arrangement sequences from the experience of a representative sample of older Americans. These analyses produce some novel empirical insights about the sequence of living arrangements among older persons and gender differences in these sequences.

Multistate Life Tables of Older Americans' Living Arrangements

The second analysis chapter seeks to answer a hypothetical question: at a given age how much longer can older persons expect to live in general and depending on their initial living arrangement? This is done by summarizing projected living arrangements derived from modeling observed transition experiences of older adults between 1998 and 2012. In particular, the expected years of life and expected time spent in an institution may vary substantially depending upon initial living arrangements at different ages. The implications of such projections should help us to evaluate whether and the degree to which living alone is a risk factor related to adverse outcomes. Employing multistate life tables (MSLT), the analysis is able to consider transitions among multiple living arrangements and draw upon the mathematical properties of MSLT functions to generate summary measures of the implications for these dynamic transition processes. Population-based life tables are used to calculate total life expectancy and state-specific life expectancies for the overall population. Since individuals arrive at older ages occupying different living arrangement statuses, status-based life tables are estimated to

investigate the lifetime implications of living alone or not for older persons surviving to a particular age.

These MSLT analyses are based on an assumed Markov model for living arrangement transitions operating in discrete time as many well-established studies have done (See Laditka & Hayward, 2003). The Markov models assume that the transition rates are solely dependent on the current state and independent of the duration in the state or any past history (Tuma & Hannan, 1984). The Markov models also allow for unobserved transitions within an interval, a strength that has been utilized by research using survey data collected at widely spaced intervals.

The MSLT analyses produced empirical results with important implications toward the influence that living arrangements may have on the health of older persons living alone in the community. In contrast to much of prior research that suggests the mortality risk associated with living alone, the MSLT analysis results suggest that living alone is not associated with shorter life expectancy relative to living with someone for women at all ages and for men at older old ages.

Subsequent Living Arrangements of Older Americans Who Are Living Alone

After examining summary implications of the dynamic living arrangement transition processes, the third analysis chapter takes a multivariate approach to examining time until transitioning out of living alone and factors that trigger and influence transitions to the multiple destinations including co-residence, institutionalization, and death. The discrete-time empirical analysis begins with an examination of the literature regarding push/pull factors affecting the living arrangements of older persons. Employing a sample of older respondents who are first observed living alone during the

fourteen year study period, event history analysis methods are used to investigate what are the individual characteristics that may explain why some older persons who are living alone make a particular transition whereas others do not. In addition to examining the broad effects of demographic and family factors on transitioning from living alone, these analyses also specifically examine the effects of progressive longer term declines in health, as well as the effects of incident sentinel or precipitating major health events and functional status changes during the time period of living alone. These empirical analyses provide important empirical insights about the effects of culture, kin availability, and health factors on the risks of transitions from living alone and gender differences in these effects

Data

The study compiles data from eight waves of the biennial Health and Retirement Study (HRS) with the baseline set at 1998 and follow-ups extended to 2012. The study sample includes all community-dwelling respondents aged 65 and over at baseline. In other words, age-eligible respondents at baseline who are institutionalized at the time of interview are excluded.

An important issue that had to be addressed in this dissertation was sparse data on some living arrangement transitions between biennial HRS surveys. Death is the only living arrangement transition destination that is truly a permanent outcome. When biennial living arrangement transitions were first compiled, relatively few respondents institutionalized in time 0 reported their living arrangement status as living in the community in time 1. While this may largely reflect the continued need for nursing home care for many respondents, individuals also experience short-term nursing home stays

followed by a return to community residence. Since the HRS asks respondents in what year and month they changed to the living arrangement status observed in the present wave, these self-reported dates were used to retrospectively construct a between-wave living arrangement status at the midpoint between two HRS interviews or twelve months prior to the present interview for respondents that allowed for annual assessment of living arrangement status. This approach helped to alleviate the issue of the sparse transitions, particularly those involving institutionalization. The annual transition data suggest that biennial transitions are less effective to capture the transitions in and out of institutionalization because some post-acute nursing home stays may only last several weeks or months, substantially shorter than two years, and that institutionalization and death are closely related. The annual transition data contained greater variety in transition counts that more closely resembles transition patterns that would be observed in shorter time intervals. In each of the major analyses, the data structure that was best suited for the specific research design was employed. The sequence and MSLT analyses employed annual transition data, and biennial data were employed in the discrete time event history analysis.

Closing Remarks

In short, the three analyses of this dissertation research pose different assumptions and perspectives of analysis. The first sequence analysis makes no assumption and displays the patterns of living arrangement sequences with minimum manipulation. In the second multistate life table analysis, an underlying Markov process is assumed. By invoking this assumption we are able to calculate average years of life in total and in distinct living arrangements that older persons expect to live and examine implications of

living alone holding all population rates constant. The third analysis employs multinomial logistic regression analysis to assess the influences of various factors and the impact of living alone history on the relative risks of transitioning from living alone to other residence states and death. Although the empirical results from these three analyses may not be directly comparable, they provide different perspectives that should help to improve our understanding about older Americans' living arrangements and inform the development of policies aimed at enhancing their quality of life.

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CHAPTER 2

LIVING ARRANGEMENT SEQUENCES AMONG OLDER AMERICANS

Introduction

Older adults' living arrangements over time compose a collective life history that varies by subgroups of individuals. The variation not only exhibits in its patterns of transitions but also in sequence that at a similar point of time, different individuals choose to make one transition instead of others. Older adults' living arrangements not only indicate whom they live with but also implicitly suggest social exchanges between the individual and other household members (Wilmoth, 2000). Thus, the significance of changes in living arrangements for older persons lie in the fact that the prior exchange will be subsequently altered in addition to the household compositional changes. As older persons approach even older ages and exhibit more diverse patterns of living arrangements, a simple question becomes critical: What do older Americans' living arrangements look like over time?

Since the 1990s, there have been studies examining sociodemographic factors that explain changes in living arrangements using logistic regression models or event history analysis (Mutchler & Burr, 1991; Mutchler, 1992; Richards, White, & Tsui, 1987; Soldo, Wolf, & Agree, 1990; Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Wilmoth, 2000; Wolf & Soldo, 1988; Worobey & Angel, 1990). Other research

emphasized the deteriorating effect of certain types or transitions of living arrangements on institutionalization or death that are defined as adverse health outcomes using similar techniques (Davis, Neuhaus, Moritz, & Segal, 1992; Kasper, Pezzin, & Rice, 2010; Koskinen, Joutsenniemi, Martelin, & Martikainen, 2007; Martikainen, Moustgaard, Murphy, Einiö, Koskinen, Martelin, & Noro, 2009; Rogers, 1996; Wolinsky, Callahan, Fitzgerald, & Johnson, 1992). While few studies adopt a longer-term perspective on older persons' living arrangements, Wilmoth (1998) described the relationship between age and transitions among community-based living arrangements and toward institutionalization and death using multiple-decrement life tables.

The study takes another approach to describe older Americans' living arrangement by viewing each individual's living arrangements over time as a unique course of life history. An older person's living arrangement sequence is an ordered collection of living arrangement states observed annually during the observation period. Identical successive living arrangement states constitute an episode of the living arrangement state in the sequence. In this study, I first describe subsequent transitions in living arrangements by episodes in living arrangement sequences and then apply sequence analysis (SA) to sequences data on the annual living arrangement states of 9,947 age-eligible respondents of Health and Retirement Study (HRS) from 1998 through 2012.

Respondents reach at the baseline arrangement observed in 1998 at different ages and in different years. Since the study data only span a particular period of time without information on prior living arrangements, it is not possible to assess the duration of the respondents' 1998 baseline living arrangements. While factors that led to the baseline

arrangement in 1998 may still affect and interact with other factors that the respondent subsequently encountered in the later life, this study does not address how and why these respondents occupied these living arrangement states at baseline. Instead, this study focuses on the subsequent living arrangements of respondents, describing how these respondents proceeded in their life course with respect to their living arrangements, examining whether these living arrangement sequences differ, and investigating whether there are common pathways of living arrangement sequences. Specifically, the study includes three research questions:

1. Do subsequent transitions in baseline living arrangements vary by baseline living arrangement for older men and women?
2. What are the intermediate living arrangements after baseline arrangements for older men and women who departed from baseline arrangements?
3. What are the general patterns of living arrangement sequences for older men and women?

Methodology

Data

The study utilizes data from the Health and Retirement Study (HRS), a biennial and nationally representative survey for Americans aged 50 and over, first implemented in 1992. In 1998, The HRS was joined by the Survey of Asset and Health Dynamics Among the Oldest Old (AHEAD) and supplemented sub-samples, constituting a well-represented sample of Americans who were born prior to 1947 at the time. For the current study, the baseline was set at 1998 and included community-dwelling respondents aged

65 and older at baseline as the study sample. With follow-ups extended to 2012, we are able to observe the study sample up to 14 years.

The positions of living arrangement states refer to a relative time point in a sequence (Brzinsky-Fay, Kohler, & Luniak, 2006). Older men and women are first observed in baseline living arrangements at different ages in 1998, and some of them subsequently die or depart for other living arrangements afterward. To help alleviate some potential age and cohort effects, the study differentiates two age groups: 65 to 74 years old and 75 years and older. Although the older age group contains a small number of men (n=408) and women (n=854) who were aged 85 and over, the overall patterns of living arrangements for the age group are not substantially changed when they are omitted. The monotonic sequences toward death among these oldest old persons were similar to some of persons aged 75 to 84 who died subsequently.

Eight waves of biennial data are available directly from the core HRS data files. Six living arrangement statuses between biennial interviews are constructed from responses about when living arrangements changed. The HRS asks respondents in what year and month they and their household members changed to the living arrangement status observed in the present biennial interview. These self-reported transition dates are used to retrospectively construct a between-wave living arrangement status at the midpoint between two HRS interviews or twelve months prior to the present interview in odd years from 2001 to 2011. Essentially, one additional pseudo observation point is added at the middle of the biennial interval prior to the present interview. Because the self-reported transition dates for household members and children were first available in

2002, the between-wave statuses of the study sample are constructed for every odd year since 2001. The unavailable 1999 status was addressed with imputation.

Using the original HRS biennial status along with the constructed between-wave status allows us to assess one's living arrangement status annually with an increased variety that better resembles transition patterns that would be observed in shorter time intervals. While its limitations are acknowledged, to facilitate the analysis, it is assumed that a living arrangement transition, if any, occurs at the middle point between two annual interview dates. With this assumption the length of a living arrangement state is thus measured in years.

The annual transition data show that biennial transitions are less effective in capturing shorter living arrangement episodes, such as the transitions in and out of institutionalization because some post-acute nursing home stays may only last several weeks or months. However, even with annual observed transition data, we would still miss some living arrangement episodes, such as short-term institutionalizations, that may end before or begin after the pseudo between-wave interview date. In addition, measuring duration in discrete year units certainly will exaggerate the length of identified living arrangement episodes, particularly institutionalization, which may be actually shorter than one year. With clear limitations, the constructed annual transition data are still valuable in providing information that biennial data do not have.

Living arrangement states

In the current study, living arrangements are defined hierarchically by checking the following statuses at the time of biennial or between-wave pseudo interview dates accordingly:

(1) Whether the respondent was alive?

(2) Whether the respondent was living in an institution?

(3) Whether the respondent was living with a spouse or partner?

(4) Whether the respondent was living with at least a child, if not living with a spouse or partner?

(5) Whether he or she lived was living with at least one household member, if not living with a spouse/partner or child?

By imposing the hierarchical definitions on household composition, answers to the five questions above identify six different living arrangements: (1) living alone (without any household member present), (2) living with other persons, such as relatives or nonrelatives (without a spouse or partner or child present), (3) living with children (without a spouse or partner present; may include other persons), (4) living with spouse or partner (may include children or other persons), (5) institutionalization, and (6) death.

It is important to note that these living arrangement statuses are constructed hierarchically so that they are mutually exclusive. The hierarchical living arrangement scheme is directly linked to the residency of a key household member, such as a spouse or partner, or a child. Any change in living arrangements thus represents the departure or addition of a specific kind of household member. Certain types of transitions in living arrangements cannot be captured in this hierarchical scheme—such as children departing from a nuclear family and leaving empty nest parents, or when two older adults combine their households through marriage, and adult children, relatives, or nonrelatives are present in one or more household.

The National Death Index (NDI) is used as the primary source of information for determining mortality status, when the NDI report is available and is different from the proxy response in the HRS exit interview. The most recent NDI match was conducted in 2008. Since the cross-sectional HRS mortality status variables are based on proxy reports, the mortality status was updated accordingly if a respondent's death record was matched by NDI. For nonrespondents whose mortality status is obtained via the NDI match, his or her mortality status is carried forward to the first annual interview date following the date of death, and the living arrangement statuses between the last valid interview and all annual interviews preceding the date of death are left as nonresponse.

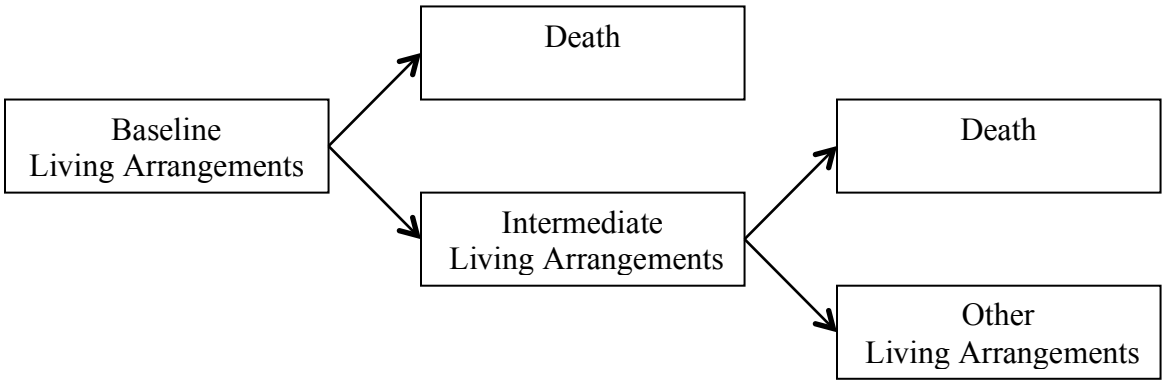
Analytic plan

The first and the second research questions are addressed by describing observed sequences of living arrangement episodes. Episodes are defined as the period of time, measured in years, over which an individual has the same living arrangement state. This is distinguished from an annual living arrangement state, defined at the individual's living arrangement state in a specific year. A living arrangement episode essentially consists of a set of identical successive annual living arrangement states. Since living arrangement episodes vary in duration, these first descriptive analyses only describe changes in the succession of living arrangements that occur over the observation period regardless of the duration of the living arrangement episode. These descriptive analyses investigate the general tendencies of destination-specific transitions made after residence in the selected living arrangement first observed at baseline. This part of analysis is not based on transitions in annual living arrangement states, but based on transitions in living arrangement episodes observed in a sequence. Annual transition rates provide cross-

sectional information on living arrangements. However, transitions in episodes of living arrangements more closely follow one's movement in living arrangements over time. As the following analyses show, on average, older person experience no more than three living arrangement episodes of varying duration during the 14-year observation period. This provides an opportunity for depicting older persons' living arrangement transitions in greater detail.

As Figure 2.1 displays, the first set of descriptive analyses are focused on at most two potential subsequent transitions over fourteen years: (1) transitions from a baseline living arrangement to an intermediate living arrangement, and (2) transitions from an intermediate living arrangement that follows the baseline state to a third potential living arrangement. In other words, the analysis only considers at most three different living arrangement states: a baseline state, an intermediate state, and a third state. The living arrangement sequences considered thus far take no account of how long persons spend in different living arrangements after the baseline arrangement. The first set of transitions from baseline arrangements are defined by (1) the transition type: stay, death, or departure; and (2) destination intermediate arrangements: co-residence with someone, living alone, and institutionalization. The second set of transitions from an intermediate living arrangements are illustrated graphically for easier apprehension, using index plots suited for presenting sequence data. One's living arrangement sequence over time is illustrated by listing annual living arrangement states horizontally from left to right. Individuals are plotted along the y-axis, while each individual' annual living arrangement states are illustrated along the x-axis by different colors representing different living arrangement states.

Figure 2.1. Subsequent Transitions in Living Arrangements



The third research question about whether patterns exist among living arrangement sequences is addressed more rigorously through sequence analysis that applies two analytic techniques—Optimal Matching (OM) algorithm and cluster analysis—on annual living arrangement sequences (Brinzinsy-Fay et al., 2006; MacIndoe & Abbott, 2004). First, OM algorithms are used to calculate a distance measure between each pair of longitudinal sequences observed in respondent-level data. This distance measure reflects the similarity between any given pair of sequences. Second, standard cluster analysis is performed on the distance matrix measuring the degree of similarity among pairwise sequences to determine natural groupings or clusters of the sequences observed for individual respondents. The result clusters are used to classify the living arrangement sequences into a typology that can further serve as independent or dependent variables for questions about "what determines the sequences and what they in turn determine" (MacIndoe & Abbott, 2004, p. 338).

Optimal Matching was developed in biology for the analysis of protein and DNA sequences (Abbott & Tsay, 2000). In social science, Abbott and Forrest (1986) were among the first to apply OM algorithms in studying the figure sequences in ritual dances.

Since then, a variety of applications have been shown in studies such as social mobility over employment careers (Halpin & Chan, 1998), temporal structure of county lynching patterns in U.S. southern counties (Stovel, 2001), school-work transition patterns among young people (McVicar & Anyadike-Danes, 2002), and residential mobility history across a rural-suburban-urban place type continuum (Stovel & Bolan, 2004). Recent applications include women's career patterns among different cohorts (Simonson, Gordo, & Titova, 2011), incorporation pathways among new immigrants (Fuller, 2014), and retirement patterns and income security between two welfare regimes (Fasang, 2012).

Figure 2.2.1 contains an example of two individuals' living arrangement sequences over ten years. Individual 1 spent two years living with spouse (S) and then transitioned to living alone (A). After one year in living alone, this individual changed his/her living arrangement to living with children (C). Then, the individual decided to go back to living alone and died subsequently four years prior the end of observation period. Individual 2 spent three years in living with spouse, one year in living alone, two years in living with children, two years in living alone, and then passed away two years before the end of observation. In fact, the two individuals have the same order of living arrangement states over the 10-year period and only differ in episode duration. The elements that differ are highlighted in light grey.

Figure 2.2.1. Example of Two Annual Living Arrangement Sequences over 10 Years

Individual 1	S	S	A	C	C	A	D	D	D	D	
Individual 2	S	S	S	A	C	C	A	A	D	D	
Operations	0	0	1	1	0	1	1	1	0	0	5

To measure the distance between two sequences, the Levenshtein distance is applied in OM algorithms by counting the minimum operations to transform one sequence into the other (Levenshtein, 1966, citied from Brzinsky-Fay, Kohler, & Luniak, 2006). The fewer the operations are needed, the more similar the pairwise living arrangement sequences are. Figure 2.2.1 also shows a simple way to align the two sequences by substituting elements that differ in the two living arrangement sequences. The third element in the individual 1's living arrangement sequence is living alone (A), while the corresponding element for individual 2 is living with spouse (S). Substitution refers to the operation of replacing one element with the other. In this case, we can substitute A with S (or vica versa) to align both sequences through year 3. In addition, we see four more annual elements of sequence 1 that differ from those of sequence 2. If we substitute all five differences, resulting in five operations of substitution, an overall distance of five operations results. This is referred to as the "costs" of aligning the two living arrangement sequences.

Alternatively, Figure 2.2.2 suggests an alignment that incorporates inserting a blank element (Ø) at where the two sequences differ. A blank element is inserted at the third element of sequence 1, shifting the rest of the sequence to the right and aligns the next four elements of the two sequences. The now eighth element is substituted, leaving the aligned ninth and tenth elements. Finally, the last element of sequence 2 can be

inserted as blank; alternatively, the last element of sequence 1 can be deleted. Either way can achieve the alignment of two sequences. By three operations of substitution and insertion/deletion, we can align the two observed sequences as well. Since insertion and deletion results in the same count of operations, they are collectively referred to as *indel*.

Figure 2.2.2. Example of an Alternative Alignment of Two Living Arrangements Sequences

Individual 1	S	S	Ø	A	C	C	A	D	D	D	D	
Individual 2	S	S	S	A	C	C	A	A	D	D	Ø	
Operations	0	0	1	0	0	0	0	1	0	0	1	3

If we determine that operations of substitution and indel are equally important, the pairwise distance of sequences or the costs of transforming one into another is simply the sum of the minimum number of the above operations. In this case, an identical weight is assigned to any operation of substitution and indel. Given the two alignments, the pairwise distance or unweighted costs of the two sequences is 3 as the alignment in Figure 2.2.2.

By the simple examples of two alignments in Figure 2.2.1 and 2.2.2, we can easily see that the pairwise distance between the two sequences is smaller when substitutions, deletions, and insertions are allowed (operations=3) than if one uses only substitution (operations=5). The least costly approach to full alignment of the two sequences determines the pairwise distance between the two sequences. In practice, we must rely on the Needleman-Wunsch algorithm to determine the least costly alignment with the minimum distance among multiple possible alternative approaches to alignment (Needleman & Wunsch, 1970, citied from Brzinsky-Fay, Kohler, & Luniak, 2006).

Clearly, one may argue that on theoretical grounds some operations should be more costly than others (See Brzinksy-Fay et al., 2006; MacIndoe & Abbott, 2004). First, substitutions of two different elements can be weighted differently with respect to theoretical considerations, analytic focuses, or the empirical regularity of particular transitions. Second, indel costs can be weighted differently relative to substitution costs, reflecting a consideration of the priority of using substitution or indel to align sequences. Given the exploratory purpose of this analysis, the study chooses to use unit substitution costs (all substitutions are equally weighted) and set indel costs to be one-half of substitution costs (See Brzinksy-Fay et al., 2006; Simonson, Gordo, & Titova, 2011). The results using these costs of alignment should satisfy the exploratory goal of the study.

A study exploring grouping results by different substitution costs matrices—such as weighted, transition frequency-based, and unit substitution costs—found that well-defined careers emerge across different substitution cost settings despite minor discrepancies among complicated careers (Anyadike-Danes & McVicar, 2010). Since the actual transitions among intermediate arrangements that follow the baseline arrangements are sparse, weighted substitution costs may not substantially change the groupings identified with unit costs. Thus, it is expected that the major living arrangement sequences should be classified using the unit costs.

Because the operation of substitution can be replaced by one deletion and one insertion, it is sensible to set indel costs as half of substitution costs (Brzinsky-Fay, Kohler, & Luniak, 2006; Simonson, Gordo, & Titova, 2011). Setting indel costs greater than half of the largest substitution cost would prevent the algorithms from using indels, whereas setting indel costs much lower than substitution costs would make the algorithms

tend to use indels for alignment (Brzinsky-Fay, Kohler, & Luniak, 2006; MacIndoe & Abbott, 2004). In Figure 2.2.3, the pairwise distance becomes 2 if we set the indel cost as half of the substation cost; in addition, the pairwise distance become even smaller—only 1.2—when we set indel costs at 1/10 the substitution cost. This smaller distance with low indel costs relative to substitution costs suggests that the algorithms are more likely to pick up alignments in which indels are used. Some argue that indels distort timing of transitions (Fuller, 2010; Lesnard 2010); other suggest that if relative positions of episode is the key, one should allow indels by setting lower weights of indel costs (Brzinsky et al., 2006; MacIndoe & Abbott, 2004). Although living arrangement episodes are of interest to the study, we have no information on the beginning of living arrangement states observed at baseline due to left truncation. Therefore, setting lower weights on indel costs relative to substitution costs may exacerbate the already unaligned sequences due to left truncation with unclear consequences. The study takes the neutral way by setting the indel cost as half of the substitution costs.

Figure 2.2.3. Example of Cost Assignments of Two Living Arrangement Sequences

Individual 1	S	S	Ø	A	C	C	A	D	D	D	D	
Individual 2	S	S	S	A	C	C	A	A	D	D	Ø	
Operations	0	0	1	0	0	0	0	1	0	0	1	3
Cost 1 (sub=1; indel=0.5)	0	0	0.5	0	0	0	0	1	0	0	0.5	2
Cost 2 (sub=1; indel=0.1)	0	0	0.1	0	0	0	0	1	0	0	0.1	1.2

The OM analysis was performed using the Stata SQ ado-files (Brzinsky-Fay, Kohler, & Luniak, 2006). The hierarchical cluster analysis with Ward's linkage method was performed using Stata with its standard procedures (StataCorp, 2011a). Stata provides two stopping rules for determining the best grouping in cluster analysis. In

addition, the cluster tree and/or index plots also provide visual clues about the strength of the clustering and distinct patterns of groupings.

Missing Data

Sequences containing missing elements or statuses must be excluded from sequence analysis because individual sequences are unit of analysis. Imputing missing data in sequences can reduce the number of cases excluded from analysis. However, appropriate imputation approaches must consider the facts that these missing data tend to be consecutive and take the form of gaps (Halpin, 2012, 2013). Note that multiple gap episodes of different lengths may appear in a sequence at different positions. In particular, patterns of missing data in living arrangement sequences are closely related to the approach that constructs the between-wave statuses. Detailed discussions about the patterns of missing sequence data are included in the Appendix B.

The study imputed missing sequence data with maximum gap length up to three years of the 10,758 respondents aged 65 and older at baseline (see Appendix B for the imputation method). Before any imputation, about 77% of sequences are complete. About 23% of sequences would have been excluded from analysis because of a gap in information about living arrangements in some years. After imputation, 811 of age-eligible respondents (8%) with missing data gaps greater than three years were excluded from the following analyses; 9,947 respondents (92%) were retained for the following analyses, including 4,239 men and 5,708 women.

T-tests and Chi-squared tests shown that sequences with gap length greater than three years belong to respondents who were younger, healthier, having higher household income. They tend to be female, married, less likely to live alone but more likely to live

with a spouse or partner at baseline, and less likely to be retired. These characteristics are generally associated with lower likelihood for living arrangement transitions (Liang, Brown, Krause, Ofstedal, & Bennett, 2005; Longino, Jackson, Zimmerman, & Bradsher, 1991; Mutchler, & Burr, 1991; Speare, Avery, & Lawton, 1991; Worobey & Angel, 1990; Spitze, Logan, & Robinson, 1992). The omission of respondents with lengthy gaps in their living arrangement sequences should not substantially affect the results of analyses of transition patterns, because actual transitions in living arrangements are less likely to occur among such respondents.

Results

The results section is organized in two major sections. The first section contains a descriptive analysis of baseline living arrangements and up to two transitions in living arrangement episodes. The second section examines sequences of annual living arrangement states and employs sequence analysis, using optimal Matching (OM) and cluster analysis methods to identify major regularities in sequences of living arrangement states.

In the first section, the baseline living arrangements in the sample are described first. Then, the first and the second research questions are addressed by examining transitions from the baseline living arrangements to the first intermediate living arrangement that follows the baseline living arrangement. Next, sequence index plots are used to provide visual illustrations about any subsequent transition that follows these intermediate living arrangements.

In the second section, actual frequencies of the full sequences of living arrangement episodes and sequences of annual living arrangement states are first

presented. These data illustrate the diverse patterns of sequences that occur and the relatively small numbers of individuals with identical sequences of annual living arrangement states. Next, the sequence analysis results from application of the OM algorithms and cluster analysis yielding information about "similar" sequences are presented to address the third research question.

Descriptive Analysis of Baseline Living Arrangements and Subsequent Living Arrangement Episodes

Baseline Living Arrangements by Gender and Age

For men or women aged 65 to 74, living with spouse is the dominant baseline living arrangement, followed by living alone as shown in Table 2.1. In particular, the vast majority of men of the younger old lived with spouse or partner (83%), while 60% of women of similar ages did so. About 12% of men and 26% of women in this age group lived alone at the baseline line. Other baseline living arrangements are less frequent for both genders in the age group, except for a small proportion of the younger old women who lived with children (10%).

Table 2.1. Percentage Distribution of Baseline Living Arrangements by Age Group and Gender

	Age 65 to 74		Age 75 and older	
	Men	Women	Men	Women
Baseline arrangement (%)				
Couple	82.7	59.6***	66.6	25.7***
Alone	12.2	26.4	21.1	45.5
With Children	3.0	9.6	4.9	14.1
With Others	1.7	4.0	2.0	5.5
Institution	0.4	0.5	5.4	9.3
Percentage of Deceased	54.5	42.1***	89.3	83.7***
N	2,412	2,739	1,827	2,969

Note: Numbers and percentages unweighted. *p<.05. **p<.01. ***p<.001.

For those aged 75 and older, the dominating initial status of living with spouse remains the same for men but not for women. Among the older old men, living with their spouse is still prevalent (67%), in spite of the higher prevalence of living alone (21%) in this age group. However, older old women are less likely to live with spouse (26%) and more likely to live alone (46%) relative to older men. Women in this older age group had more diverse living arrangements at baseline than women in the younger age group and older men. More specifically, living with children (14%), in an institution (9%), or living with others (6%) are more prevalent baseline living arrangements among older old women relative to their younger older women and older old male counterparts.

Among those in the younger subgroup, 55% of men and 42% of women died during the 14-year observation period. Among those age 75 and over, 89% of men and 84% of women died sometime before the end of observation period. Such high mortality rates indicate the critical role of mortality in shaping the sequences of living arrangements in later life.

Table 2.2 contains counts of the number of living arrangement episodes that older persons experienced over the 14-year period. An episode of living arrangement is defined by a span of one or more consecutive years in which an individual lives in the same living arrangement state. Except for the absorbing mortality state, one may experience the same living arrangement state in more than one living arrangement episode over time. That is, an individual may transition to a different living arrangement state and subsequently transition back to the former living arrangement state later in time. The average number of living arrangement episodes experienced by men and women over the 14-year period is between two to three. Whereas, on average, men and women aged 65 to

74 respectively had 2.0 and 2.3 episodes of living arrangements, men and women aged 75 and older had 2.4 and 2.6 episodes, respectively. The medians of episode numbers are two for older persons in the four age-gender subgroups.

Table 2.2. Distribution of Numbers of Living Arrangements Episodes by Age Group and Gender

	Age 65 to 74		Age 75 and older	
	Men	Women	Men	Women
Number of Episodes				
1	31.3	26.0	4.5	4.4
2	47.4	41.6	61.0	50.5
3	15.2	19.0	24.0	30.2
4	4.4	8.6	7.0	10.0
5	1.3	3.3	2.8	3.2
6	0.3	1.0	0.6	1.5
7	0.2	0.5	0.1	0.2
8	0.1	0.0	0.0	0.0
Mean	1.99	2.27 ***	2.44	2.62 ***
(S.D.)	(0.94)	(1.15)	(0.86)	(0.97)
Median	2	2	2	2
N	2,412	2,739	1,827	2,969

Note: Numbers and percentages unweighted. *p<.05. **p<.01. ***p<.001.

The distributions of counts of living arrangement episodes show that 47% of men and 42% of women aged 65 to 74 have two living arrangement episodes over the 14-years. The corresponding percentages among those aged 75 and older are 61% for men and 51% for women. The next most frequent numbers of episodes is one episode for persons aged 65 and older (31% for men and 26% for women), and three episodes for persons aged 75 and older (24% for men and 30% for women).

Having one episode of living arrangements suggests that the person has no change in his or her baseline living arrangements throughout the observation. Having two episodes of living arrangement states indicates that the person experienced the baseline living arrangement and one intermediate arrangement before censoring, or the person

experienced the baseline living arrangement and died subsequently because mortality is considered a living arrangement state. Similarly, having three episodes of living arrangement states suggests that the third episode may either be a living arrangement state different from the intermediate state that immediately followed the baseline state, or the mortality state. These distributions of living arrangement episodes indicate that men tend to have fewer living arrangement episodes than women ($t=-13.0$, $p<.001$), and older old persons tend to have more living arrangement episodes than the younger old ($t=-20.8$, $p<.001$).

To summarize, the dominant status of living with spouse is evident among older persons, except for women aged 75 and older who tend to live alone. Compared with the younger age group, a higher percentage of men and women aged 75 and older were observed living alone at baseline. Nearly half of the older old women lived alone in particular. Women in either age group were less likely to live with spouse but more likely to have diverse living arrangements—such as live alone, with children, with others, or in an institution—than their male counterparts. The varying counts of living arrangement episodes by gender and age group suggest possible gender and age differences in living arrange transitions. Since the counts of living arrangement episodes do not reflect the actual living arrangement states, the following analyses are based on these static characteristics at baseline and examine the continuity and progression of one's living arrangements. Due to high mortality rates at older ages and few living arrangement episodes that they experienced, the subsequent transitions of older men and women's baseline arrangements are inevitably restrained.

Subsequent Transitions in Baseline Living Arrangements by Gender and Age Group

After the first observed living arrangements at baseline, older persons may stay in the baseline living arrangements throughout the observation, die sometime afterward, or transition out of the baseline arrangement to an intermediate arrangement as shown earlier in Figure 2.1.

As shown earlier in Table 2.1 that men aged 65 to 74 were disproportionally observed as living with spouse or living alone at baseline, Table 2.3 shows the distribution of the first intermediate living arrangement states of older persons by age group and the two baseline living arrangement states. The first panel of the table shows that a slightly higher percentage of men aged 65 to 74 who lived either with a spouse or alone at baseline both die subsequently without making any change in their baseline living arrangements (39% and 43%, respectively) relative to the other two transition patterns. Whereas the next most likely outcome among men living with spouse at baseline in this age group was to maintain the baseline living arrangement (35%), men living alone at baseline were next most likely to transition to an intermediate living arrangement such as living with someone else (39%).

On the other hand, women of similar ages were more likely to depart for an intermediate arrangement than to make no change in their baseline living arrangements. Although the majority of women aged 65 to 74 lived with spouse at baseline, 53% of them departed from this baseline arrangement to an intermediate living arrangement, such as living alone or with an individual other her spouse, before death or censoring up to fourteen years later. Likewise, a large proportion of women initially living alone (44%) transitioned to a different living arrangement during the observation period.

Table 2.3. Percentage Distribution of Living Arrangement Transitions and Intermediate Living arrangements by Gender and Age Group

	Men		Women	
	Baseline arrangement		Baseline arrangement	
	Couple	Alone	Couple	Alone
Aged 65 to 74				
No Change	34.8	17.3***	26.5	29.6***
Followed by Death	38.8	43.4	20.9	26.7
Followed by Intermediate Arrangements	26.5	39.3	52.6	43.7
N	1,995	295	1,631	723
Age 75 and older				
No Change	5.6	2.6 **	2.5	7.2***
Followed by Death	57.2	53.0	30.8	39.5
Followed by Intermediate Arrangements	37.2	44.4	66.8	53.3
N	1,217	385	764	1,351

Note: Numbers and percentages unweighted. No change indicates censoring at the end of observation. *p<.05. **p<.01. ***p<.001.

The second panel of Table 2.3 shows that, among persons age 75 and older at baseline, very few men or women were able to maintain their baseline arrangements. To even greater extent than those who were younger, men aged 75 and older were likely to die subsequently without making any change in baseline living arrangements than women, and women of similar ages were likely to transition to an intermediate living arrangement than their male counterparts. Over half of the men in this older age group living with spouse (57%) or living alone (53%) died subsequently. In contrast, the majorities of women initially coupled (67%) or living alone (53%) transitioned to an intermediate living arrangement.

As shown earlier in Table 2.2, men have fewer episodes of living arrangements than do women. That may be partly because men tend to die subsequently after baseline arrangements, while women tend to make at least one transition to an intermediate living arrangement. At the same time, it is also observed that the proportions of transitioning to

an intermediate living arrangement are generally higher among men (Chi2=432.9, p<.001) or women (Chi2=493.8; p<.001) who were aged 75 and older than their younger counterparts. Not only do mortality rates increase with age, but also transition rates from baseline arrangements also rise at older ages, particularly for women.

This section addressed the first research question for whether subsequent transitions from baseline living arrangements vary by baseline arrangement. In general, the descriptive results show differences in transition patterns. Within each gender and age group, whether an individual tended to stay in the baseline living arrangement, die before making any transition, or depart for a different living arrangement depended upon whether the individual lived with a spouse or alone at baseline. Nonetheless, with minor, but consistent differences in the two baseline arrangements, it appears that for both age groups men are more likely to die before making any change in baseline living arrangements than women, and women tend to depart for an intermediate arrangement after their baseline arrangements. The similarity of transition patterns within gender is evident. These tendencies are even greater among those aged 75 and older.

Intermediate Living Arrangements by Gender and Age Group

As we have observed the varying subsequent transitions following one's baseline living arrangements, we turn to the second research question concerning what the destination living arrangements are if these older persons departed from their baseline living arrangements. Table 2.4 shows that the percentage distributions of three types of intermediate living arrangements: (1) co-residence with someone (aggregated to include living with spouse or partner, children, or other persons); (2) living alone; and (3) institutionalization. Men and women who transitioned to co-residence are a complex

group of people with different baseline arrangements and in different intermediate co-residence arrangements. Transitions to living alone or in an institution also differ in ways, such as whether it is voluntary or out of necessity. Even though the subsequent transitions after baseline arrangements differ by gender and to less extent by age group and baseline arrangement, the intermediate arrangements are surprisingly similar for men and women but differ largely by age group and baseline living arrangement.

Table 2.4 contains information about the distribution of the types of first intermediate living arrangement states among older persons who transition out of their baseline arrangement by age group and baseline living arrangement state. Although initially coupled men aged 65 to 74 were less likely to make a transition than their female counterparts, both genders have very similar distributions of intermediate living arrangements associated with their baseline arrangements. The first panel of Table 2.4 shows that among those who transitioned to an intermediate arrangement, men or women initially living with spouse were more likely to subsequently live alone or in an institution than to co-reside with someone else. Among those who made a transition the majority of men (56%) and women (68%) who lived with a spouse transitioned to living alone, while another 26% of men and 15% of women coupled at baseline transitioned directly to an institution. Since Table 2.3 showed that more than half of women initially living with spouse departed from it to an intermediate living arrangement, and Table 2.4 shows that about two-third of these women transitioned to living alone, 36% of women initially living with spouse went on to live alone as their first intermediate transitions, suggesting that initially coupled women tend to live alone after marital dissolution.

Table 2.4. Percentage Distribution of Intermediate Living arrangements by Baseline Arrangement, Gender, and Age Group

	Men		Women	
	Baseline arrangement		Baseline arrangement	
	Couple	Alone	Couple	Alone
Age 65 to 74				
Co-residence	18.2	65.5***	16.7	66.5
Spouse or Partner	-	(32.9)	-	(17.1)
Children	(78.1)	(38.2)	(81.1)	(48.6)
Other Persons	(21.9)	(29.0)	(18.9)	(34.3)
Alone	55.9	-	68.2	-
Institution	26.1	34.5	15.2	33.5
N	528	116	858	316
Age 75 and older				
Co-residence	15.9	43.9***	17.3	36.7
Spouse or Partner	-	(21.3)	-	(5.3)
Children	(76.4)	(45.3)	(85.2)	(58.7)
Other Persons	(23.6)	(33.3)	(14.8)	(36.0)
Alone	54.8	-	60.8	-
Institution	29.4	56.1	22.0	63.3
N	453	171	510	720

Note: Numbers and percentages unweighted. Conditional percentages listed in parentheses for three subgroups of co-residence. *p<.05. **p<.01. ***p<.001. Numbers in parentheses are percentages for three co-residence living arrangements that add up to 100.

Men or women initially living alone were more likely to transition to co-residence with someone—such as a new spouse or partner, children, or other persons—than to living in an institution. Among individuals who made a transition, about two thirds of men or women initially living alone transitioned to co-residence with someone, leaving a third of men or women entering an institution as their first transition since baseline. The co-residence living arrangements were most likely to be with children; the next most likely co-residence that follows living with children are living with spouse for men (33%) and living with persons other than a child—such as relatives or nonrelatives—for women (33%).

Men and women aged 75 and older tend to choose similar intermediate arrangements that are associated with their baseline arrangements as those in the younger age group. The second panel of Table 2.4 shows that older old men and women had intermediate living arrangements similar to the younger old who were initially living with spouse but sharply different from those who were initially living alone.

Similar to the younger counterparts, 68% of men and 61% of women aged 75 and older who made a living arrangement transition chose to live alone after departing from living with spouse, followed by 15% of men and 22% of women directly enter an institution subsequently. Unlike their younger counterparts, the majority of men or women initially living alone (69% for men; 63% for women) entered an institution as their first subsequent living arrangement after baseline. Similar to their younger counterparts, living with children is the most likely option among the men or women transitioning to co-residence with someone from both coupled and living alone baseline living arrangements.

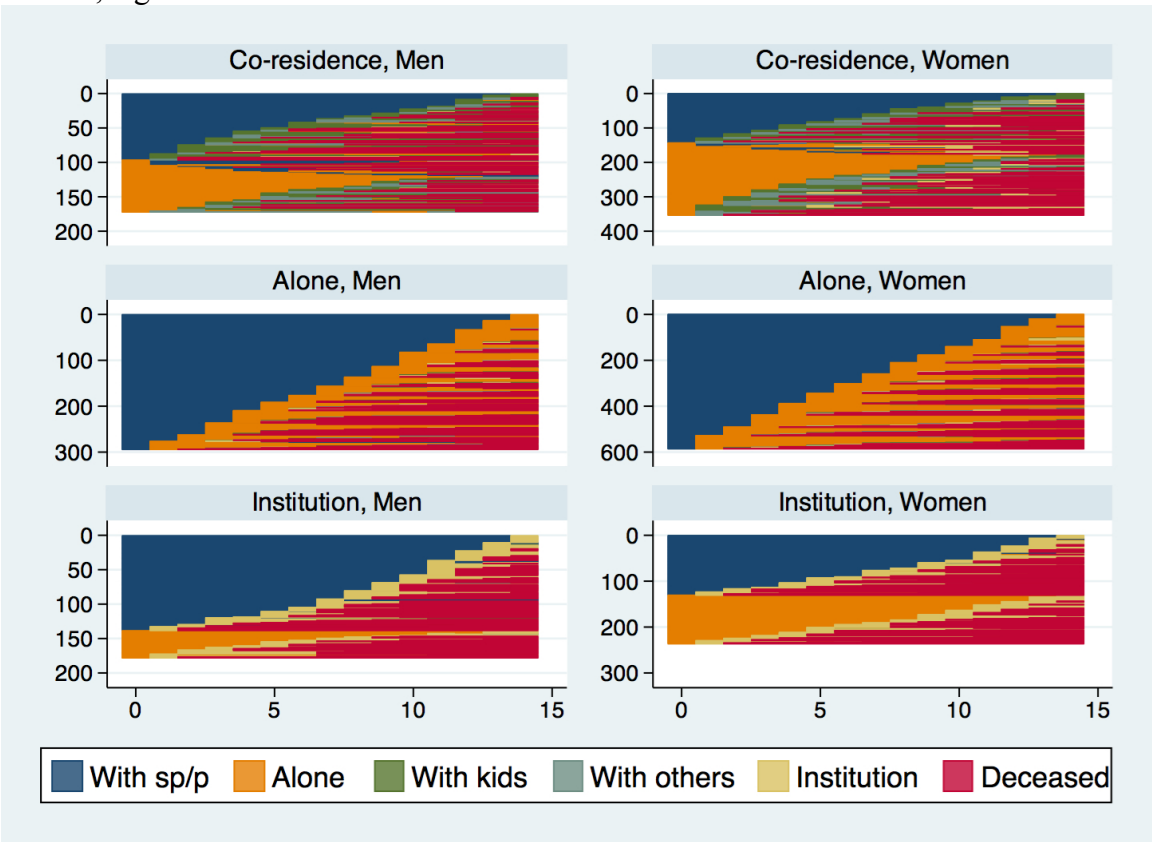
Sequence Index Plots by Intermediate Living Arrangements over Time

Regarding the subsequent transitions that follow these older persons' intermediate living arrangements, descriptive information based on the few who departed is not sufficient to reach substantive conclusions, except for large proportions of death after intermediate arrangements (data not shown). Instead, visual illustrations for subsequent transitions are shown in Figure 2.3.1 and 2.3.2 by gender and three intermediate living arrangements. These index plots illustrate living arrangement sequences among those who departed from two baseline living arrangements to three intermediate arrangements as described in Table 2.4.

The individual living arrangement sequences for men and women described in the first panel in Table 2.4 were graphed in Figure 2.3.1 by their subsequent intermediate arrangements, The collections of individual sequences that are stacked on top of each other show living arrangements for each of the fourteen years starting from baseline for respondents who experienced an intermediate arrangement of either co-residence, living alone, or institutionalization. By stacking these individual sequences, we can more easily observe the duration of these intermediate arrangements, timing of subsequent transitions, and destination arrangement of subsequent transitions. These annual living arrangement states are depicted in different color horizontally from year 1 to year 15. These plots clearly suggest that the numbers of sequences displayed differ substantially. Figure 2.3.1 and 2.3.2 are also rescaled to a fixed interval of the number of sequences to give better visualization for small groups.

Similar to what was shown earlier in Table 2.4, Figure 2.3.1 and 2.3.2 illustrate that among men and women who depart from living with spouse or alone for co-residence with someone, that individual is likely to be a child. Very diverse sequences of living arrangements appear among this group of older persons as indicated in the complex patterns of subsequent transitions following intermediate co-residence. Next, the orange areas that border the blue areas suggest that large proportions of men or women initially living with spouse departed for living alone, a pattern that is consistent for both genders in two age groups. In addition, coupled women who transition to living alone seem to subsequently live alone longer than do men; persons aged 75 and older at baseline appear to depart from living with spouse relatively earlier than their younger counterparts, presumably due to their advanced age.

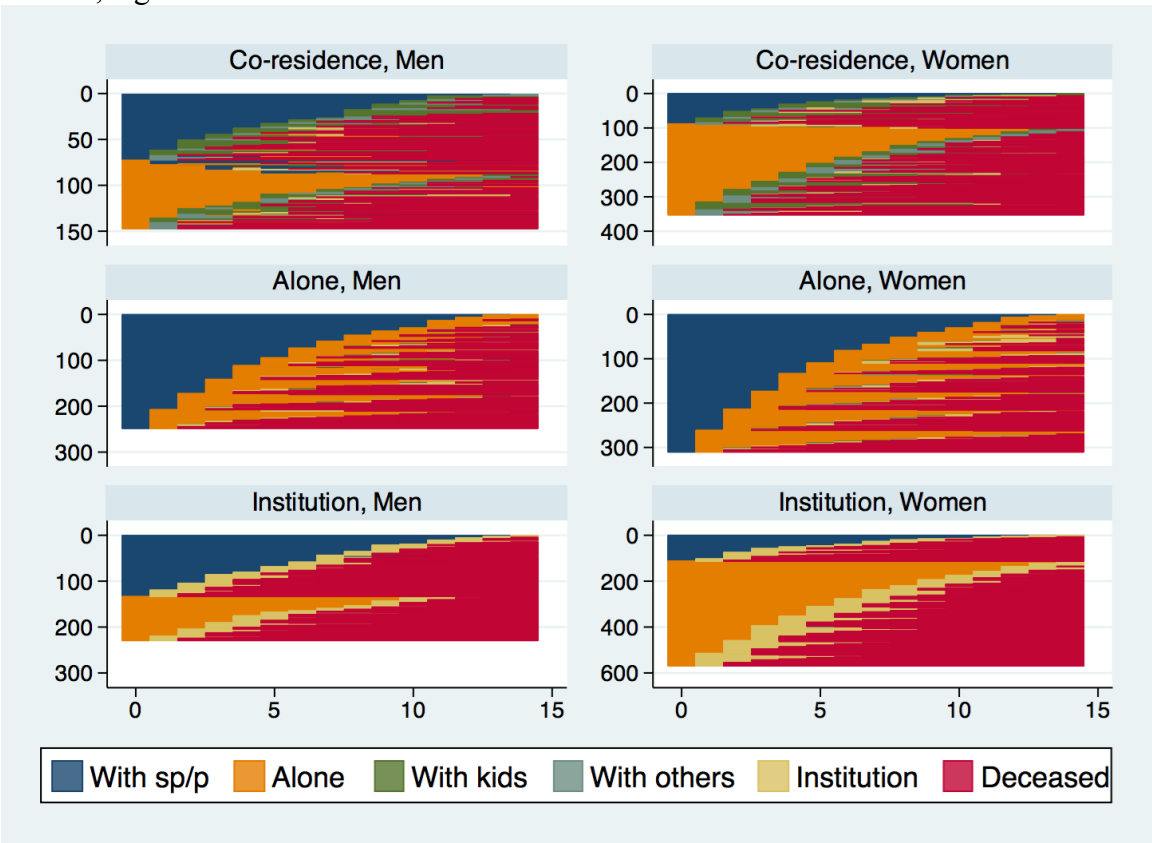
Figure 2.3.1. Living Arrangement Sequences by Intermediate Living Arrangement and Gender, Age 65 to 74 at Baseline



While the duration of living alone varies, the subsequent transition of men and women whose intermediate arrangement after baseline is living alone, is likely to be death as indicated by the red areas in two middle plots for men and women. Lastly, after baseline, some men and women may enter an institution. Women aged 75 and older at baseline who entered an institution were more likely to have lengthier stay than their male counterparts as well as men and women of younger ages, as indicated in the thick tan areas following the two baseline living arrangements. The vast majority of these institutionalized persons died subsequently after varying tenures of residency in an institution as indicated by the tan areas (institutionalization) that are followed almost

exclusively by red areas (death). In other words, the great majority of persons who are institutionalized do not transition back to community residence either alone, coupled, or with others.

Figure 2.3.2. Living Arrangement Sequences by Intermediate Living Arrangement and Gender, Age 75 and Older at Baseline



To summarize the results of the descriptive analyses thus far, the choices of the intermediate living arrangements after baseline appear to vary by baseline arrangement and age group. Despite distinct transition patterns following the baseline arrangements, the intermediate arrangement choices for men or women are rather similar. In particular, men or women initially living with a spouse tend to transition to living alone regardless of age group. For men or women initially living alone, the options of the next living

arrangement transitions tend to be co-residence with someone among those aged 65 to 74, and an institution among those aged 75 and older at baseline.

From the visual illustrations of actual sequences intermitted by each of the three intermediate living arrangements, we speculate that the intermediate arrangements can either be a transient state before mortality or a lengthy gateway to less common living arrangement transitions and mortality as well. While most of the variation in the sequences is attributable to differences in the first two living arrangement episodes, the general patterns of living arrangement sequences may be largely associated with the first two episodes of living arrangements. Beyond the second living arrangement episode, we observe sparse transitions to other living arrangement states and relatively large transitions to mortality. The two index plots also show large variations in duration of intermediate living arrangements as well as the timing of the transitions to these intermediate living arrangements. The simple descriptive analyses based on episodes of living arrangements thus far do not account for timing of transitions and duration in episodes of living arrangements. To address the issues of timing and duration, the following analyses use analytic techniques that consider sequences as a whole.

Sequence Analysis of Living Arrangements

The above descriptive analyses considered episodes of baseline living arrangements and transitions to subsequent intermediate living arrangements. The length of living arrangement episodes (duration of successive identical living arrangement states) and the positions of living arrangement states (relative timing of transitions) were not considered. The following analyses first describe the older persons' ordered sequences of living arrangement states as a whole. Sequence analysis methods are

employed to analyze whether there are meaningful general systematic patterns in these annual sequences of living arrangement states over a 14-year period.

Sequence analysis treats entire individual sequences as the unit of analysis. These sequences differ by the order of the episodes of living arrangements and/or by the lengths of those episodes. In sequence analysis, the OM algorithms are employed to calculate pairwise distances between any given pair of living arrangement sequences as a measure of similarity, which in turn become input for a cluster analysis that determines if there are distinct groupings of living arrangement sequences.

The following analyses have two purposes. First, enumerating the actual sequence of living arrangements for all individuals provides simple descriptive information about the most common patterns and introduces the analysis of entire sequences. Second, by using a distance measure to quantify the similarity between different sequences for each pair of individuals, cluster analysis may be used to identify a typology of distinct sequence patterns that do not require common sequences to be identical.

Sequences of Living Arrangement Episodes

Before examining the most common sequence patterns of annual living arrangement states over the fourteen-year period 1998-2012, ordered sequences of living arrangement episodes are examined. Table 2.5.1 and 2.5.2 describes common sequence patterns by listing the five most frequent living arrangement patterns with a similar order of living arrangement episodes for individuals aged 65 to 74 and 75 years and older, respectively. We consider sequences to have the same pattern if these sequences have living arrangement episodes that occur in the same order. For example, the sequence pattern “1-6” is used to describe individual annual sequences over four years, such as 1-

6-6-6, 1-1-6-6, and 1-1-1-6. In all of these four-year sequences, death (6) follows the baseline state of living with a spouse (1) even though the duration of time the individual lives with a spouse after baseline varies.

Among men aged 65 to 74, all individual living arrangement sequences can be characterized by 147 unique sequence patterns of living arrangement episodes (Table 2.5.1). The five most frequent episode patterns characterize about 75% of individual sequences. In particular, the two most frequent episode patterns—living with spouse followed by death (32%) and continuously living with spouse (29%)—account for about 61% of individual sequences. On the other hand, women aged 65 to 74 exhibit 268 different sequence patterns of living arrangement episodes. The five most frequent episode patterns account for about 54% of these women's individual living arrangement sequences. About 16% of them were continuously living with spouse; 13% were living with spouse followed by subsequent death; 11% were living with spouse and followed by a transition to living alone. The sequence patterns of living arrangement episodes for men aged 65 to 74 appear to be more clustered than for women, possibly due to the greater diversity of unique sequences of women's living arrangements.

Table 2.5.1. Five Most Frequent Sequence Patterns of Living Arrangement Episodes among Older Persons Aged 65 to 74

	Men		Women	
	String	%	String	%
Rank				
1	1-6	32.1	1	15.7
2	1	28.8	1-6	12.5
3	2-6	5.3	1-2	10.6
4	1-2	5.2	2	7.8
5	1-5-6	3.5	2-6	7.1
Sum		74.9		53.6

Note: 1 = living with spouse, 2 = living alone, 5 = institutionalized, 6 = deceased. In total, there are 147 unique sequence patterns for men and 268 sequence patterns for women.

For men aged 75 and older, a total of 132 unique sequence patterns of living arrangement episodes were identified. The five most frequent sequences shown in Table 2.5.2 account for about 65% of all individual sequences. Two patterns of subsequent death immediately after either living with spouse (38%) or living alone (11%) cover nearly half of all individual sequences. For women aged 75 and older, there were 233 unique sequence patterns of episodes identified. About 53% of individual sequences are accounted for by the five most frequent patterns. About 18% of older old women died after living alone. The next most frequent pattern for older women is living alone, followed by institutionalization, and then death (11%). In the older age group, both men and women's living arrangement sequences of episodes are more likely to end in death.

Table 2.5.2. Five Most Frequent Sequence Patterns of Living Arrangement Episode among Older Persons Aged 75 and older

	Men		Women	
	String	%	String	%
Rank				
1	1-6	38.1	2-6	18.0
2	2-6	11.2	2-5-6	10.9
3	1-5-6	5.8	5-6	8.2
4	1-2-6	5.6	1-6	8.0
5	2-5-6	4.6	3-6	7.7
Sum		65.3		52.7

Note: 1 = living with spouse, 2 = living alone, 5 = institutionalized, 6 = deceased. In total, there are 132 sequence patterns for men and 233 sequence patterns for women.

Sequences of Annual Living Arrangement States

Sequences patterns of annual living arrangement states are examined next. In this instance, each year is distinguished as a separate living arrangement state. Two individuals with identical sequences of living arrangement episodes will only have identical annual sequence patterns if both the order and duration of each living

arrangement episode are the same. Table 2.6.1 and 2.6.2 list the ten most frequent annual living arrangement sequences for older men and women. Men and women aged 65 and older exhibit 532 and 911 unique sequences of annual living arrangement states, respectively, when living arrangement states of each year are distinguished. The most frequent annual sequence is continuously living with spouse for both men (29%) and women (16%) aged 65 to 74 (Table 2.6.1). The rest of the most frequent annual sequences included continuously living alone or with a child, and living with spouse followed by living alone or death at varying time points. All other unique annual living arrangement sequences were relatively infrequent for both men and women.

Table 2.6.1. Ten Most Frequent Sequence Patterns of Annual Living Arrangement State among Older Persons Aged 65 to 74

	Men		Women	
	String	%	String	%
Rank				
1	111111111111111	28.8	111111111111111	15.7
2	111666666666666	2.9	222222222222222	7.8
3	166666666666666	2.9	333333333333333	2.2
4	111166666666666	2.7	111111111111222	1.7
5	111111111111333	2.6	111666666666666	1.4
6	116666666666666	2.6	111111111111122	1.1
7	111111166666666	2.5	166666666666666	1.1
8	111116666666666	2.3	111111666666666	1.1
9	111111116666666	2.3	111111111114444	1.0
10	222222222222222	2.1	111166666666666	1.0
Sum		51.6		34.1

Note: 1 = living with spouse, 2 = living alone, 3 = living with children; 5 = institutionalized, 6 = deceased; In total, there are 532 sequences for men and 911 sequences for women.

For men and women aged 75 and older, individual annual sequences are all small percentages (Table 2.6.2). Overall, we observe 533 and 1024 unique sequences of annual living arrangement states for men and women, respectively, in the age group of 75 and older. There is not a very common annual sequence for person at older old ages. Men

appear to be more likely to be living with spouse followed by death than women, while the most frequent sequences for women tend to begin with living alone and followed by death. The transitions to mortality state do not appear to concentrate at a particular time point. These sequences with small percentages beginning with the same baseline living arrangements can be aggregated as sequence patterns as shown in Table 2.5.1 and 2.5.2.

Table 2.6.2. Ten Most Frequent Sequence Patterns of Annual Living Arrangement State among Older Persons Aged 75 and older

	Men		Women	
	String	%	String	%
Rank				
1	166666666666666	5.5	222222222222222	3.3
2	111666666666666	4.8	566666666666666	2.8
3	116666666666666	4.7	222666666666666	2.5
4	111166666666666	3.9	266666666666666	2.2
5	111111111111111	3.7	222266666666666	2.1
6	111116666666666	3.1	222226666666666	1.9
7	111111666666666	3.0	226666666666666	1.8
8	111111166666666	2.7	556666666666666	1.8
9	111111116666666	2.3	222222666666666	1.6
10	566666666666666	2.0	555666666666666	1.4
Sum		35.6		21.3

Note: 1 = living with spouse, 2 = living alone, 5 = institutionalized, 6 = deceased; In total, there are 533 sequences for men and 1024 sequences for women.

Sequence Analysis of Annual Living Arrangement Sequences

The very low prevalence of any specific annual living arrangement sequence other than continuous living with a spouse show the difficulty to address the third research question on the general patterns of annual living arrangement sequences. These individual sequences differ in duration of living arrangement episodes, timing of transition, and multiple choices of living arrangement states at varying time points. To provide meaningful groupings or classifications of common individual living

arrangement sequences, we turn to sequence analysis, using Optimal Matching and cluster analysis.

Sequence Analysis Methodology

Optimal Matching and cluster analyses are conducted for men and women separately by age group to capture possible gendered sequence types yet distinctly varying by age. The use of separate procedures could produce very specific groupings that are difficult to interpret and compare. However, the results were actually fairly similar across the four gender-age subgroups with respect to major classifications, differing more in specific features of characterizing the major classifications. The two default numerical stopping rules used in conventional cluster analysis did not usually provide consistent cluster solutions for classifications of living arrangement sequences. As a consequence, cluster trees were used to evaluate cluster solutions that offer visual clarity to the derived clusters. Visual illustrations using sequence index plots were also used to assess crisp sequence patterns. Further details about the classification are documented in the Appendix B.

Figures 2.4 and 2.5 contain index plots of individual sequences by sequence pattern determined from cluster solutions. As shown at the y-axis of index plots, there are large differences in the number of individual sequences classified in different clusters. All the index plots are rescaled to a fixed interval of the number of sequences for the better illustration. The name assignment for sequence patterns was based on the dominant living arrangement sequences identified in the cluster and the transition patterns as illustrated in the index plots.

For older persons age 65 to 74 at baseline, there were six clusters distinguished for both men and women: *Coupled* (mostly blue), *Deceased Spouse* (mostly blue-red), *Marital Disruption* (mostly blue-orange), *Prolonged Living Alone* (mostly orange), *Early Mortality* (mostly red), and *Living with Children* (mostly green). Additionally, women were found to have two more clusters: *Transitional Living Alone* (mostly orange-red) and *Living with Others* (mostly grey). For older persons aged 75 and older at baseline, there were still six clusters identified for men and eight clusters identified for women. However, the cluster *Coupled* does not appears among these men and women; the cluster *Marital Disruption* was not found among these older old women. For men of this age group, there was an additional cluster *Transitional Living Alone* (mostly orange-red); for women in the same age group, there were two additional clusters: *Mortality after Living with Children* (mostly green-red) and *Institutionalized* (mostly tan).

Cluster Descriptions

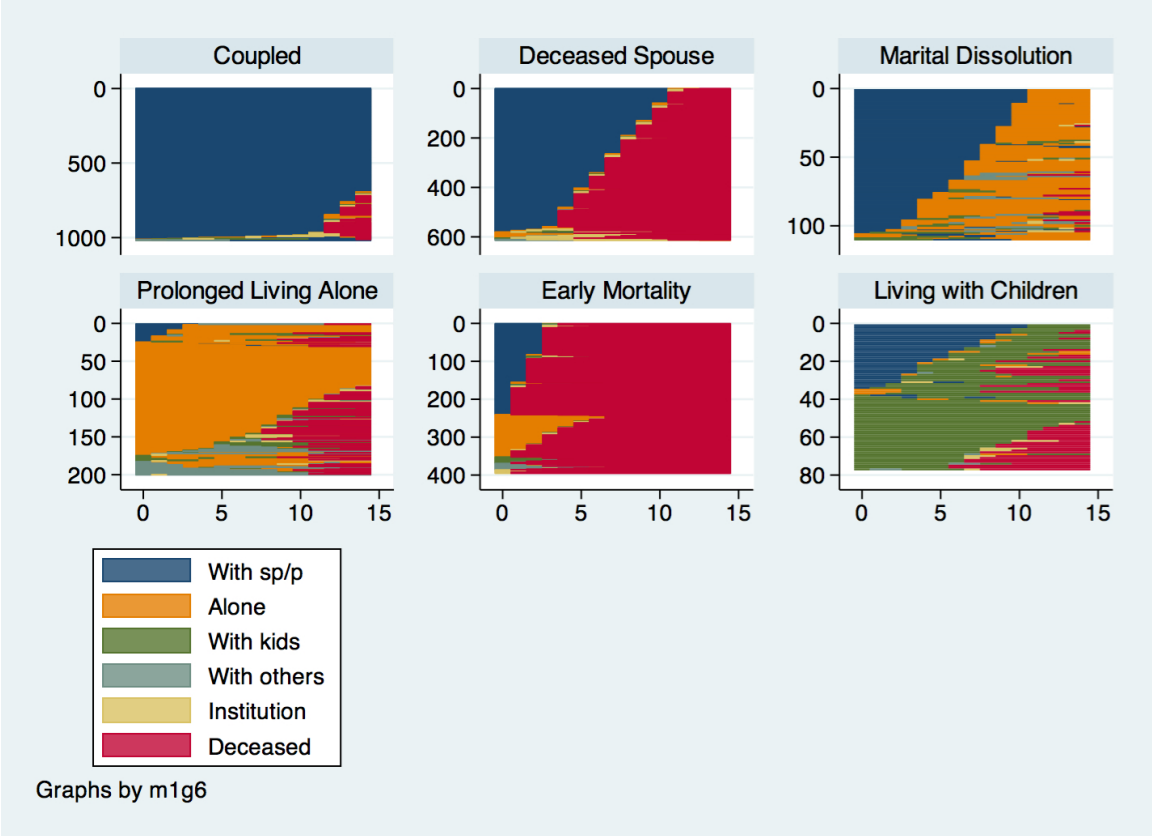
Coupled indicated a pathway of long-lasting marriage or partnership. This cluster of sequences appears among men and women aged 65 to 74 at baseline, but not among persons in the older age group. The large sample size in this cluster suggests a high prevalence of continuous marriage or partnership among men and women aged 65 to 74 at baseline throughout the observation period. As the descriptive data have shown, at the younger old ages, substantial proportions of men and women continued living with their spouse or partner throughout the 14-year period. Only a small number of sequences identified in this cluster ended in mortality at the very end of the sequences. Older persons following this pathway are advantageous because both members have to survive with intact union. The fact that *Coupled* does not appear among those aged 75 and older

suggests that the continuous marriage or partnership for extended time is highly unlikely because at least one member is likely to die at older old ages.

Deceased Spouse indicates a common pathway for men and women in both age groups. This cluster is one of the pathways from living with spouse at baseline, almost exclusively interrupted by mortality. In some cases, there may be brief episodes of living alone or in an institution between the transitions from living with spouse to the mortality state. Note that for men and women aged 65 to 74, the departure from living with spouse is concentrated around the middle of the observation period, whereas for those who were older, the timing of the departure is more spread out to include more times in the later half of the observation period. It is possible that this unexpected result may be due to this cluster containing individual sequences that would have been classified as *Coupled* if they were more distinct from *Deceased Spouse*. Nonetheless, direct departure from living with spouse to mortality state characterizes the cluster of *Deceased Spouse*.

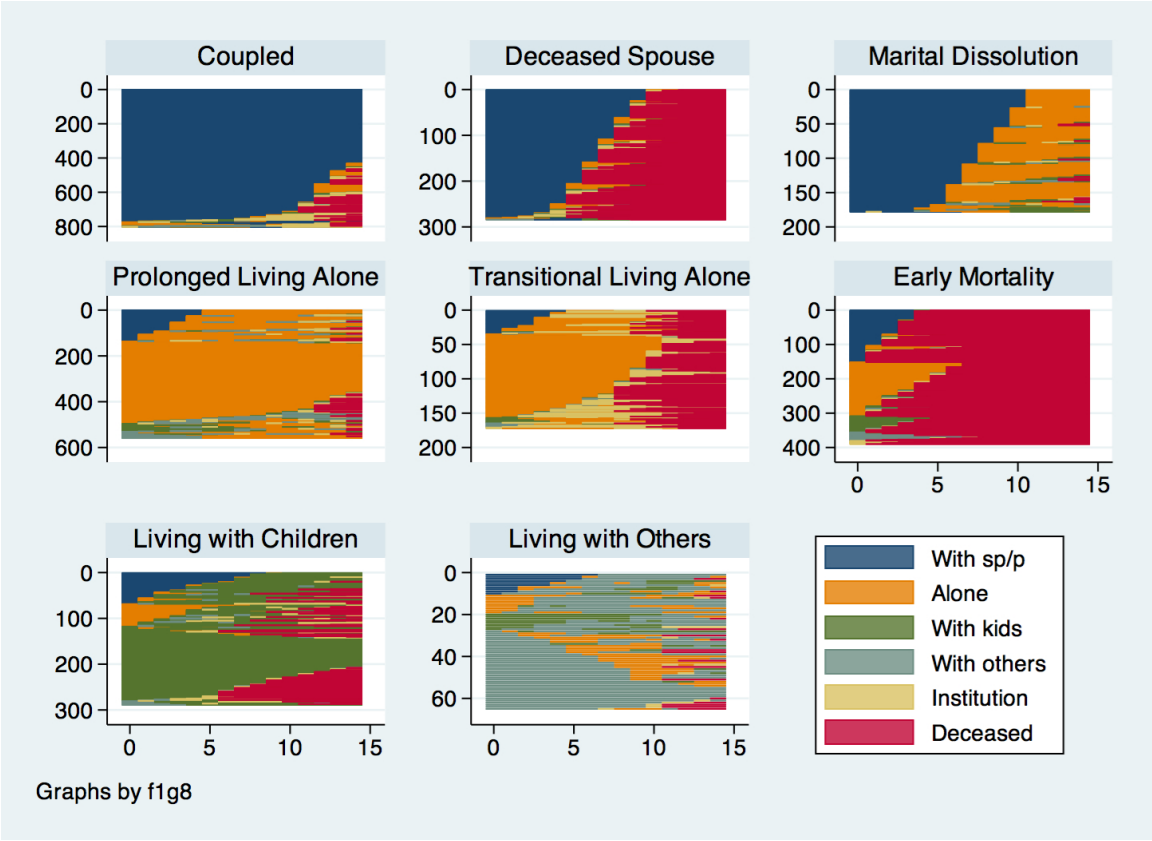
Marital Dissolution suggests a departure from living with spouse at baseline to subsequent living alone. Since we consider the respondent's household composition, the cause of the dissolution may include widowhood, divorce or separation, and simply that the couple stops living together. However, it is likely that most of these sequences belong to respondents who are surviving spouse. This pathway is observed among men and women aged 65 to 74, and only among men aged 75 and older at baseline. For men and women in the younger age group, long-lasting time spent in intermediate living alone—occasionally intermitted by co-residence or living in an institution—after departure from living with spouse is the key characteristic of this cluster.

Figure 2.4.1. Annual Living Arrangement Sequences by Cluster, Men Aged 65 to 74



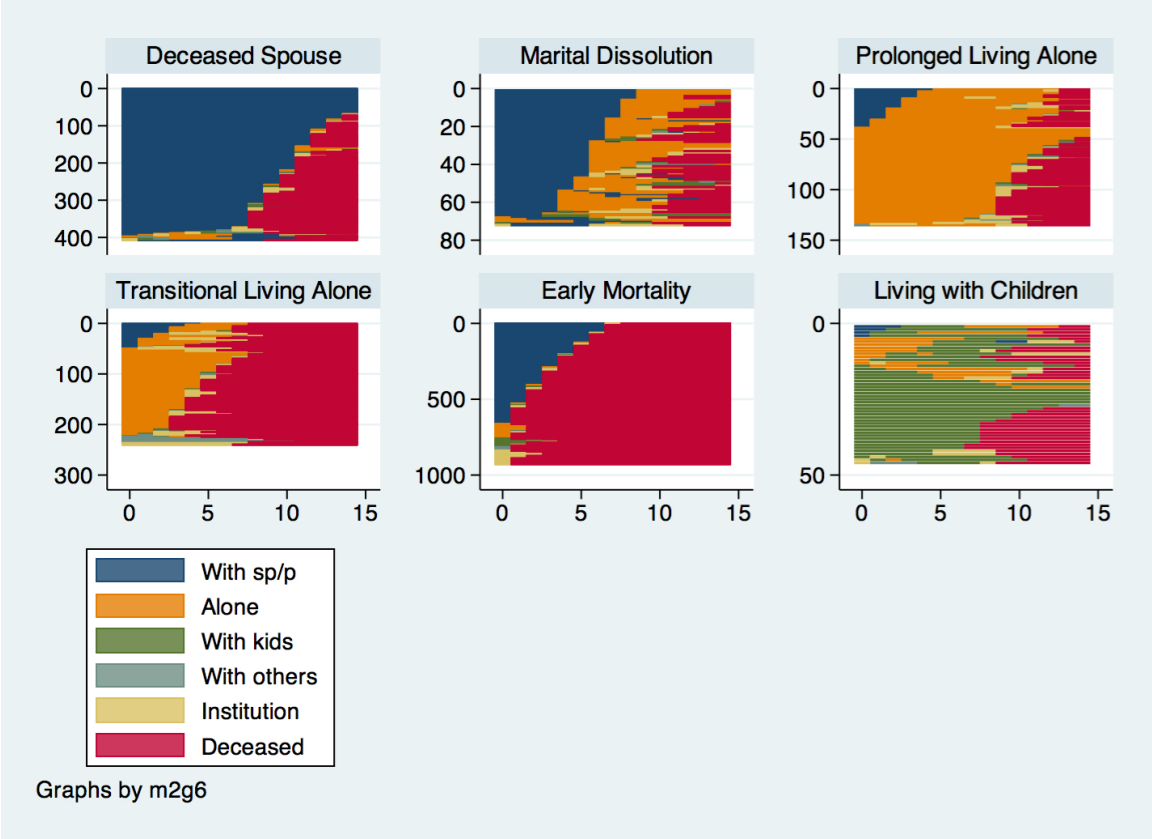
For men aged 75 and older as illustrated in Figure 2.5.1, the intermediate living alone is relatively short and terminated by mortality at the later part of the sequences, suggesting a short-lived intermediate living alone arrangement for older old men. This pattern is not identified among women age 75 and older possibly because few of these women's spouse or partner survive to older old ages. Likely, many coupled women of the age group may have departed for living alone prior to the beginning of the observation period. In addition to large numbers of women aged 75 and older initially living alone classified in *Early Mortality*, the next two clusters—*Prolonged Living Alone* and *Transitional Living Alone*—can support for the speculation.

Figure 2.4.2. Annual Living Arrangement Sequences by Cluster, Women Aged 65 to 74



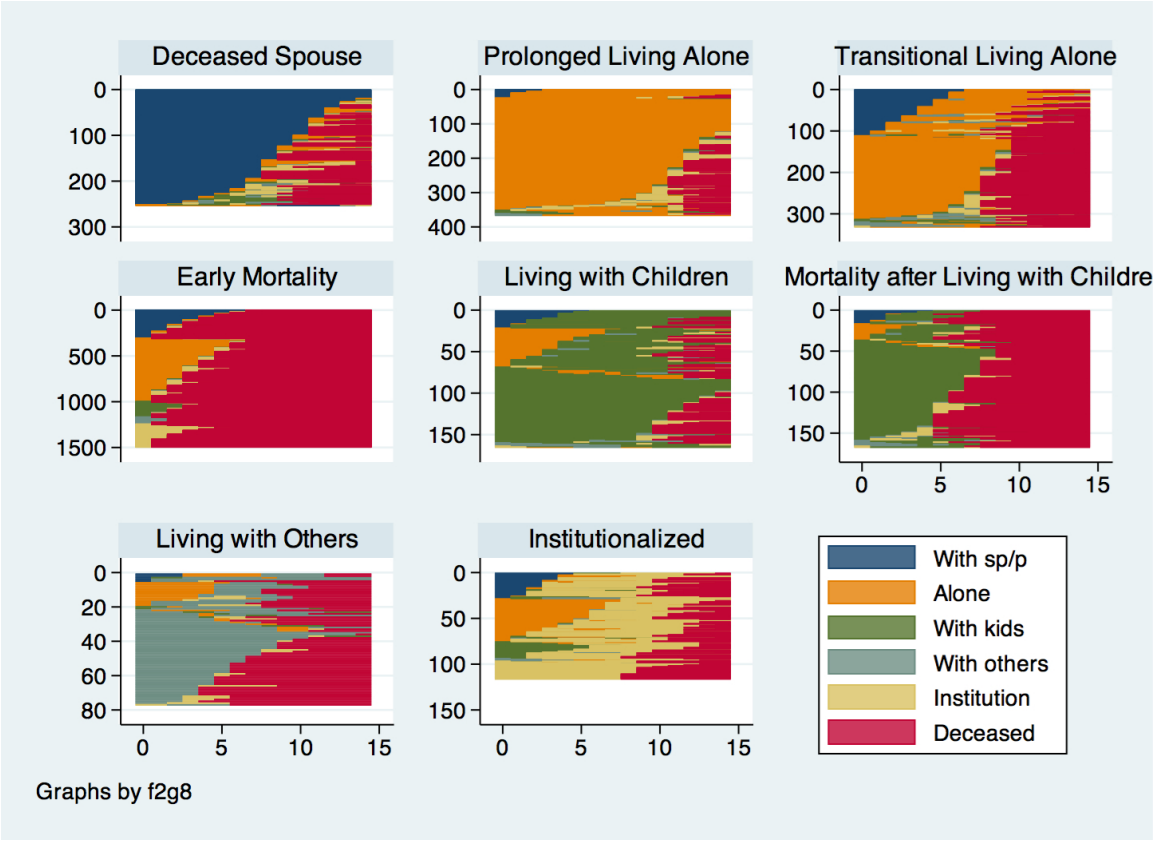
Prolonged Living Alone identifies individuals who spend extended time in living alone. Sustaining living alone in one's living arrangement sequences appears in all men and women of both age groups. These individuals were mostly observed living alone at baseline. Some of them may have long been single; others may have transitioned to living alone prior to the observation period. Depending upon baseline arrangement, gender, and age, this group of sequences may be intermitted by intermediate living arrangements, but the episode of living alone may be sustained over time or eventually be terminated by mortality.

Figure 2.5.1. Annual Living Arrangement Sequences by Cluster, Men Aged 75 and Older



Transitional Living Alone is only identified among women aged 65 to 74 and men and women age 75 and older. The living arrangement sequences of this cluster are characterized by relatively earlier mortality than *Prolonged Living Alone*, rather complex transitions and varying living arrangement sequences, and/or by larger proportions of transitions into living alone early on during the observation. Even though the duration of living alone since baseline identified in the cluster is unknown, the identification of this cluster may suggest an alternative pattern of living alone that is characterized by shorter episodes of living alone.

Figure 2.5.2. Annual Living Arrangement Sequences by Cluster, Women Aged 75 and Older



Early Mortality is a group that is consisted of men and women who departed from their baseline arrangements, with or without intermediate arrangements, toward mortality very early during the observation. In addition to those in other living arrangements observed at baseline, substantial proportions of men living with spouse or women living alone were also grouped in this cluster. From visual inspection, only a few brief intermediate arrangements following initial arrangements were observed, suggesting fast transitions into mortality.

Living with children is a cluster specified both for men and women, but numerically, much fewer men are classified in this cluster than women. Living with

children suggests a pathway that is mainly consisted of the state of living with children. Possibly due to the fact that women are more likely to live with children at baseline and relatively earlier than men, living with children is identified as an important arrangement for women. In addition, among women aged 75 and older, an additional cluster *Mortality after Living with Children* is identified for characterizing the faster pace toward mortality among those spent extended time in living with children.

Living with Others exclusively appears as a cluster among women. Among baseline living arrangements, living with others is not frequently observed among men or women. However, women living with others at baseline or transitioning to living with others since baseline spent extended time in this living arrangement state. Although the number of women's living arrangement sequences classified in the cluster is small, the classification nevertheless suggests that *Living with Others* is a distinct pathway for women.

Lastly, *institutionalized* suggests a unique pathway that is only observed among women aged 75 and older at baseline. These women from various baseline arrangements spent extended time in an institution before entering the mortality state. Although sequences with lengthy institutionalization can also be found in *Transitional Living Alone* among women in the younger ages group, these sequences are determined to be similar enough to other sequences within the cluster of *Transitional Living Alo*ne rather than a distinct cluster among younger women. However, interpretation of lengthy institutionalization should be interpreted with caution since consecutive institutionalization states may not indicate consecutive residency in an institution due to

data limitations that made it difficult to distinguish shorter post-acute stays from long-term institutionalization.

Discussion of Sequence Analysis Results

The Optimal Matching algorithms and cluster analysis identify distinct groupings of individual annual living arrangement sequences that are highly associated with baseline living arrangements and following subsequent transitions. Men's sequence groupings are basically associated with the type of living arrangement resulting from subsequent transitions in baseline living arrangements and timing of mortality. Women's sequence groupings suggest the importance of living alone and the significance of multiple living arrangement pathways starting from baseline living arrangements. Over the 14-years of observation, the majority of older persons exhibit rather simple living arrangement sequences characterized by one or two living arrangement episodes until death or being censored. As the descriptive information suggests, only a minority of older persons experienced three or more living arrangements. Individuals with these more complex sequences can be barely seen in the sequence index plots possibly because the timing of these transitions is spread out. Despite different transition tendencies by age, gender, and baseline arrangement, the patterns of simple living arrangement sequences remain rather consistent for those at older ages.

Methodologically, it is unlikely that the classification of monotonic living arrangement sequences would be different if a user-defined substitution costs matrix were specified. The sequences in different groups differ mostly because of varying baseline arrangements, duration of intermediate arrangements, and timing of mortality. Since the unit costs do not differentiate the substitution costs by any pairs of elements, the distance

measures directly reflect the operation of substitutions without differentiating the type of substitutions. The only likely difference would be in the proportions of members assigned to specific clusters because primary patterns of sequences should nevertheless emerge.

Missing sequence data are unlikely to affect the results. First, the vast majority of imputed living arrangements resulted in no transition or one single transition between the last and the next known living arrangement state (see Appendix B). No transition suggests a great stability of living arrangements if the two known state before and after the missing one are the same. Having one transition indicates the transition from the last known state to the next known state at various time points as it was imputed. Without imputing other living arrangements also suggest the stability of living arrangement over time. These imputed results coincide previous findings in the literature (Wilmoth, 1998) and thus are not likely to bias the substantive findings in the study. Second, dropping respondents with gap larger than three years is unlikely to affect the results as well because characteristics of these persons suggest that they are more likely to have stable living arrangements. Including persons with larger gaps may only increase the proportions of persons who maintain their baseline arrangements or have few transitions. Furthermore, there is a greater chance that inaccurate imputations would result when the gap is larger.

An important limitation of the study is that shorter-term institutionalization is likely to be undercounted even with annual data on one's living arrangements. In addition, the length of institutionalization episodes may be more likely to contain measurement error since living arrangements duration is measured in years. This should work better for community-based living arrangements than for institutionalization, particularly because

of potential short-term post-acute care nursing home stays. The identified institutionalization can be either short-term or long-term. Consecutive institution residency as identified here can be truly a single long-term stay or two or more institutionalizations scattered in the same time point in the year for consecutive years.

The limitations caused by left truncation and right censoring should be properly acknowledged even though they are not likely to affect the findings. Due to life truncation, we have to compromise on observing older persons' living arrangements beginning at arbitrary ages. Departure from living with spouse to living alone may represent similar processes that only differ by timing of departure, which could occur before or after the baseline. For those living alone at baseline, it is not possible to know whether and for how long they have been always living alone or how long they had been living alone after living with spouse. Fortunately, timing of transitions after baseline appears to be distributed relatively evenly at early, middle, or later part of the observation period, suggesting that the classifications are affected by left truncation only to a small degree. In addition, large proportions of younger old persons' living arrangement sequences were censored, which suggests that for persons aged 65 to 74, 14-years of observation is not long enough to observe a living arrangement transition that may eventually occur, or, in the case of death, must occur.

Discussion

In contrast to conventional analysis approaches, the study examines older persons' living arrangement sequences over a 14-year period by episodes of living arrangements and using pattern recognition techniques. The study addresses the first research question by reporting older men and women's subsequent transitions in baseline living

arrangements that vary substantially by baseline arrangement within gender and age group. Nonetheless, to a lesser extent by baseline arrangement and age group, men are less likely to transition out of their baseline arrangements, while women tend to depart for intermediate arrangements over the observation period.

The intermediate living arrangements appear to be critically linked to older persons' baseline living arrangements. The second research question was addressed by showing that men and women with the same baseline living arrangements and in the same age group tend to make similar choices of intermediate living arrangements when departing from their baseline arrangement. For men and women departing from living with their spouse at baseline, living alone is the most frequent choice of intermediate living arrangements, a pattern that remains the same for older persons aged 75 and older as for their younger counterparts. For those aged 65 to 74, the majority of men and women living alone at baseline departed for co-residence with someone, and the co-resident tends to be a child. The tendency to transition from living alone to living with children remains among men and women aged 75 and older, even though institutionalization becomes the most likely transition among persons in this older group. Even with elevated risks of mortality and increased needs for institutional care, men and women in the older age group still exhibit rather similar tendencies in transitions from specific intermediate arrangements to subsequent arrangements as their younger counterparts.

These common intermediate arrangements serve as stepping stones for older persons entering later life with different respective baseline arrangements. Since one's baseline living arrangement largely affects his or her intermediate arrangements, we may

see baseline living arrangements entering older ages as having a remote influence on one's future living arrangement pathways, given that transitions may occur years later. Although the earlier descriptive analyses of intermediate living arrangements only included those who were coupled or living alone at baseline, those substantive results are confirmed in the Optimal Matching and cluster analysis as major sequence patterns are characterized not only by living with spouse or alone, but also other baseline living arrangements for men and women, such as living with children or living with others.

The third research questions was addressed as the clusters of living arrangement sequences demonstrate that older persons' general patterns of living arrangements are closely related to the baseline arrangements first observed and the first subsequent transition, if any, that follow. The progression of living arrangement sequences in general can be described as monotone in nature, intermitted by intermediate arrangements before reaching the mortality state or until censoring at the end of observation period. The subsequent transition patterns that follow the baseline arrangements support the grouping results of individual sequences of living arrangements. *Coupled*, *Deceased Spouse*, *Marital Dissolution*, *Prolonged Living Alone*, and *Early Mortality* are identified as distinct patterns of living arrangement sequences for either gender. The general patterns are evident for both age groups although those at older ages tend to die earlier.

Living alone is a common baseline arrangement as well as a common intermediate arrangement. It appears that the only living alone as both a baseline arrangement and an intermediate arrangement may endure or extend until the end of observation. We may speculate that as large proportion of sustained living alone characterized in the sequence groupings, representing the fact that these sequences belong

to older persons who are relatively robust in health or other conditions. In other words, they are more able to live alone. However, we cannot ignore the fact that some living alone episodes are relative brief and exist in between major living arrangement episodes, suggesting a transient nature of this type of living alone episodes. These episodes may belong to persons who are less able to live alone and thus quickly transition out of the solitary living arrangement.

The force of mortality is impossible to ignore. The underlying force shaping the living arrangement transitions, besides baseline arrangements, appears to be mortality. From the analyses of transitions, we see that most of older persons, men in particular, died after one or two living arrangements. From the clusters of living arrangement sequences, we further observe that timing of the mortality event stratifies the pathways to the end of life that are associated with baseline and intermediate living arrangements. The gender difference manifests by how older persons enter the different pathways and unfold their living arrangement sequences. The age difference manifests by the timing of mortality, which substantially restrains the remaining length of life that could be spent in other living arrangements. The causes that trigger the different paces to mortality and possibly thus the different pathways into older ages are not the focus of this descriptive analysis.

Further research stemming from the descriptive analyses reported here may be directed to the left truncation and right censoring when the data are available for the study. With additional waves of data forthcoming, we will be able to extend the observed age range to younger persons (e.g., 50 year olds) and examine how pre-retirement persons approach their living arrangements in later life, and we can expand observation

window for those age 65 and older to examining how their living arrangements unfold at later ages and possible differences by cohort.

From transition-base studies, we learned that age-specific transition rates in living arrangements for older persons are generally low but increase as risks of institutionalization or death increase at older ages. In the present study, the low transition rates shown in the literature are contextualized by illustrating living arrangement sequences and depicting general sequence patterns. Sequence analysis with Optimal Matching and cluster analysis demonstrates the unique features of older persons' living arrangement sequences. An older person tends to experience only a few living arrangement episodes. One's intermediate arrangements may interrupt or become the major component of his or her living arrangement sequences. Inevitably, the force of mortality rules out the chance of another living arrangement. With clear limitations, the sequence analysis of living arrangements demonstrates life pathways that are rather tangible. Given the generally low transition rates, observing one's living arrangement sequences as a whole over time offer a perspective that are insightful about how one's living arrangement lay out.

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CHAPTER 3

MULTISTATE LIFE TABLES OF OLDER AMERICANS' LIVING ARRANGEMENTS

Introduction

To date, few studies have quantified the average length of living arrangements in one's life course. Even fewer have examined the associations between both one's living arrangement at a particular time and the expected length of remaining life as well as expected time spent different living arrangements. The expected length and distribution of subsequent time in different living arrangements provides a general picture of an average person's life course. As they reach older ages, older persons may be observed living with someone, alone, or in institutions. Because of the strong tendency to stay in current living arrangements among older persons, knowing the difference in expected subsequent time by initial states can better illustrate life course differences in mortality risks and subsequent time spent in various living arrangements. While the influence of age on transitions is substantial and is conditional on the current states (Wilmoth, 1998), the descriptive chapter on sequence analysis has attempted to address the relationship between age and transition rates very crudely by stratifying the sample into a younger and an older group. The multistate life table (MSLT) allows for more properly addressing the varying age effect through estimates of age-specific transition rates. In Chapter 3, status-

based life expectancy and other MSLT functions are estimated to capture longer-term implications of the dynamic process of living arrangement transitions in later life.

Prior studies of living arrangement transitions

In the general literature of living arrangements, institutionalization can be treated as either a health consequence of prior living arrangements (Freedman, 1996; Kasper, Pezzin, & Rice, 2010) or an individual state of living arrangements (Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990). Given the focus on household structure and the interest of kin availability, early literature did not include institutionalization in living arrangement considerations (Wolf & Soldo, 1988; Soldo, Wolf, & Agree, 1990). However, as concerns rose regarding the increasing prevalence of living alone in the older population, including the demand for long-term care and the deficit of family caregiving resources (Freedman, 1996; Mutchler, 1992), subsequent research increasingly viewed residence in a nursing home or a long-term care facility as a living arrangement state in which one is likely to spend part of his or her life.

Researchers have argued that different static living arrangements as a household context are either advantageous or adverse for the health of household members (Freedman, 1996; Hughes & Waite, 2002; Li, Zhang, & Liang, 2009; Rogers, 1996; Waite & Hughes, 1999). Others found changes in living arrangements to be protective against risks of institutionalization (Kasper, Pezzin, & Rice, 2010). Studies concerning the aging population and corresponding caregiving needs have treated living alone as a risk factor for adverse health outcomes, such as institutionalization or mortality (Davis, Neuhaus, Moritz, & Segal, 1992; Wolinsky, Callahan, Fitzgerald, & Johnson, 1992).

By treating living alone simply as a risk factor, researchers have often assumed effects of living alone to be deleterious relative to sharing the household with other persons. In its simplest yet most profound way, living alone was conceptualized as a risk factor for institutionalization and mortality (Greene & Ondrich, 1990; Wolinsky et al., 1992; Wolinsky, Callahan, Fitzgerald, & Johnson, 1993; Wolinsky, Johnson, & Stump, 1995). A goal of this research was to search for factors explaining nursing home entry and early mortality, and ultimately help to avoid unnecessary entry or death. Thus, one's living arrangements at a distinct period of the life course were treated as being associated with the likelihood of entering a nursing home or dying in the future. Operationally, these studies distinguished living alone as opposed to living with someone else, including a spouse, children, older parents, or relatives. However, this type of research often produced conflicting results, such that living alone is not necessarily related to poor health. In contrast, one study suggested that living with persons other than a spouse may be linked to poor health (Davis Moritz, Neuhaus, Barclay, & Gee, 1997).

Whether one should view institutionalization as a living arrangements state or an adverse health outcome associated with prior, solitary living arrangements may depend on one's research questions and substantive issues. Some may argue that institutionalization does not match the typical conceptualization of living arrangements either from the perspective of household composition or short-term post-acute care. However, studies have inevitably tied living alone and subsequent institutionalization or death together with results that do not appear to be consistent. Few have been able to examine this association beyond the specification of one predictor and subsequent transitions, and to reconsider a holistic view of older persons' life course experience of

living arrangements by incorporating multiple possibilities and consider time beyond a single transition. Essentially, transitions are a one-time event, but subsequent time alive as well as time spent in institutions may be better overall indicators of the health consequences of prior living arrangements, because these measures summarize the average duration of time in a specific state and overall life, which are the results of multiple transitions in and out of living states.

Life expectancy of living arrangements

Very few studies have examined time after institutionalization. Only a few studies have been conducted to describe the expected length of community-based living arrangements prior to institutionalization and/or death (Freedman, 1996; Kasper, Pezzin, & Rice, 2010; Wilmoth, 1998). Even fewer have described community-based living arrangements and institutionalization in the same model (Martikainen, Moustagarrd, Einiö, & Murphy, 2014). Possibly due to disciplinary focus or data limitations, some studies have had to combine institutionalization and death as a single state (Wilmoth, 1998). In studies considering time until institutionalization, death has often been treated as a censored outcome (Freedman, 1996; Kasper, Pezzin, & Rice, 2010). These studies have generally emphasized different segments of the continuity of older persons' life course living arrangements.

Although not specifically focusing on older persons, Richards, White, and Tsui (1987) were among the earliest to document transition rates among living arrangements and factors that trigger the changes. Wilmoth (1998) provided important findings regarding living arrangement transitions among older persons and quantified the expected length of living arrangements before a first transition occurs. Transition rates among

community-based living arrangements generally decline with age, while transitions toward institutionalization and death substantially increase at oldest ages. Although the expected number of years of living alone or with a spouse both decreased with age, at each selected age the expected years of living alone were longer than those of living with a spouse before a transition occurred. Even so, Wilmoth (1998) was unable to provide life expectancy estimates that consider life beyond the first living arrangement transition, as the multiple decrement life tables employed in her study only considered duration of living arrangements until a change occurred.

While the data are often limited to time until institutionalization, Martikainen, Moustgaard, Einiö, and Murphy (2014) were able to consider long-term institutional care and examined older persons' expected length of life by gender and marital status with a population-based Finnish registry data. Martikainen and colleagues (2014) estimated multistate life tables for time living in the community and in an institution until death for both genders. In general, the probabilities of dying in the community or in long-term institutional care increased with age. Men faced higher risks of institutionalization and elevated mortality rates in institutions relative to women, but the probabilities of exiting institutions to return to the community steadily declined with age for both genders. Even at advanced ages, women were expected to spend slightly longer subsequent time in institutions than men, possibly due to their higher rates of entering institutions at older old ages and lower chances of returning to the community. However, this study was not able to consider multiple states of community-based living arrangements and institutionalization at the same time.

Multistate life tables

Few studies have recognized the dynamic nature of living arrangements and used a life course perspective to comprehensively examine living arrangements. Part of the reason may be due to inconsistent specification of living arrangements. Living alone has long been considered a risk factor for institutionalization as an adverse outcome. It is arguable to treat those living alone as at risk and the status as static, because those living alone have been found to have health profiles similar to those of the married (Davis et al., 1992), and families are very likely to adjust living arrangements for their ill members (Rogers, 1996).

The current study draws on Markov-based multistate life tables to estimate the expected lifetime living arrangements experienced by older adults. Instead of assuming single or multiple decrement states, multistate life tables allow for more than one living state, and transitions from one state to another before exiting the life table cohort (Schoen, 1988). This advantage is particularly important for studying living arrangement transitions, since the transitions are unlikely to be unidirectional with no return to an original state. This method is able to model life course movements among living arrangements, where one may potentially experience multiple and recurrent living arrangements over his or her lifetime.

This method relies on the Markov model, which assumes that the transition probabilities from the current state solely depend on the current state and are independent of the duration of the current state and the occurrence of prior states. Generally, these transition rates or probabilities have been estimated using longitudinal panel data with statistical methods, assuming that the transition rates are the function of being in a state at

a given age and possibly other covariates while ignoring the duration dependence (Laditka & Hayward, 2003). Recent applications of multistate life tables include studies on the switching behaviors of contraceptive approaches (Kuo, Suchindran, & Koo, 2008), family behaviors and social background among young women (Schoen, Landale, Daniels, & Cheng, 2009), retirement life course (Warner, Hayward, & Hardy, 2010), and institutional care life expectancy by marital status (Martikainen et al., 2014).

The most important advantage of multistate life tables is the ability to capture the implications of age-related changes in transition probabilities by providing summary measures of the dynamic process, such as measures of probability or proportion, duration, size, and frequency (Willekens, 1987). These measures can be unconditional or conditional on the state at a given age for which the measure is calculated from corresponding age-specific transition probabilities (Willekens, 1987). Calculated on all survivors at a given age, population-based measures are unconditional on one's initial state, describing the number of remaining years that a person is expected to live in a particular state (e.g. living alone) irrespective of an initial state. Calculated on survivors in a state at a given age, status-based measures are conditional on the initial state of a person, and thus describe the expected remaining life in a particular state for those initially in the same state. While the two types of measures are different in their meanings and calculation, both are useful tools for specific inquiries.

Before calculating MSLT functions, we have to estimate transition probabilities, mostly from longitudinal data. A synthetic cohort in the longitudinal data is the basis of the underlying stochastic processes defined by the estimated incidence rates (Laditka & Hayward, 2003). A transition between states is inferred by comparing the status measured

at the time of each interview. Due to lack of information on potential transitions within survey intervals, the approach assumes no transition occurred except for the inferred transition and hence underestimates transitions occurring between interviews (Laditka & Hayward, 2003). The degree to which the multistate life tables underestimate the transition probabilities depends on the extent to which individuals experience multiple transitions within the interval (Laditka & Hayward, 2003; Warner, Hayward, & Hardy, 2010) as well as the extent to which the interval is spaced (Wolf & Gill, 2009).

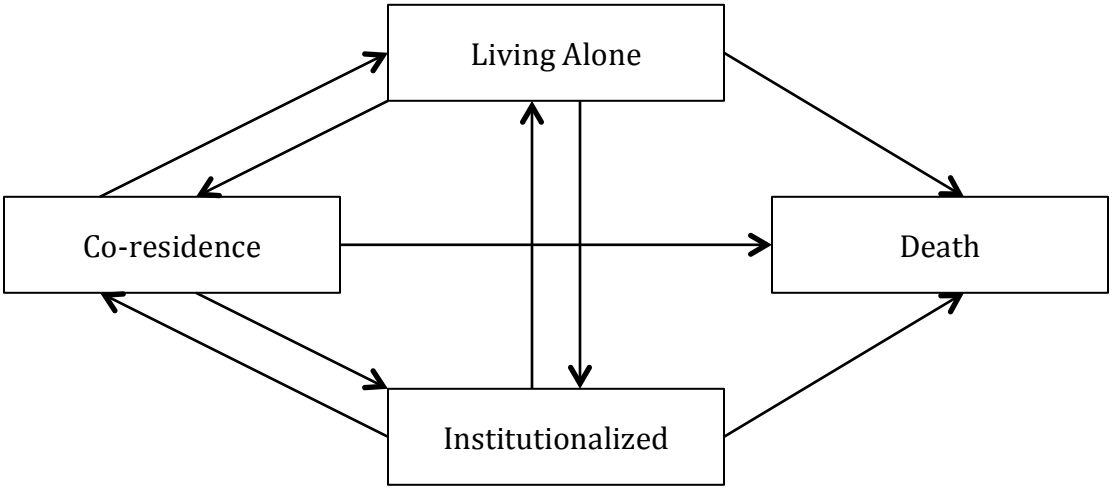
Multistate life tables for living arrangements transitions

The current study takes an alternative approach examining the interplay of community-based living arrangements and risks of institutionalization and mortality by including institutionalization and death as states of living arrangements. The study describes the dynamic process of older persons' late life living arrangement transitions and their lifetime implication by using a recently developed embedded Markov chain approach. Multistate life table software—Interpolating Markov Chain (IMaCh)—is used to recover embedded Markov chain parameters that consider transitions of shorter intervals embedded within a survey interval with multinomial logistic regression models. MSLT are estimated to calculate overall expected length of remaining life distributed in individual states as well as differentiated by one's observed status at a given age. In doing so, we are able to gauge the differences of life course living arrangements by one's initial living arrangement, fully taking into account lifetime transitions.

Drawing on the 14-year experiences of older Americans from the Health and Retirement Study (HRS), the current study estimates the multistate life tables from data on older men and women's transitions among four mutually exclusive living arrangement

states: co-residence with someone, living alone, institutionalization, and death. The first three states are not absorbing, suggesting possible subsequent transitions out of these states. The fourth state, death, serves as the only absorbing state. When an individual enters this absorbing state, he or she of course remains in the state without having any subsequent transition. In total, nine transitions are defined to illustrate older persons' lifetime experience in living arrangements, including transitions between co-residence and living alone, entering and exiting institutions, and dying following the other three living arrangements (See Figure 3.1).

Figure 3.1. Multistate Life Table Models for Living Arrangement Transitions



Four research questions are addressed through multistate life tables:

1. What are the age patterns in transition and mortality rates of living arrangements for men and women?
2. What are the age patterns in prevalence rates of three living arrangements for men and women?

3. How large are the differences in total and state-specific expectancy at given ages for men and women?
4. How does total life expectancy vary by initial living arrangement state at given ages for men and women?

Methodology

Data

Data for the study come from the Health and Retirement Study (HRS), a longitudinal study administered biennially on a sample of Americans aged 50 and older since 1992. The HRS was joined by the Study of Asset and Health Dynamics among the Oldest Old (AHEAD) and other subsamples in 1998, comprising a well-represented national sample for Americans born prior to 1947 at the time. The current study drew on this comprehensive sample by following community-dwelling respondents aged 65 and older over a 14-year period between 1998 and 2012.

The current study used baseline data in 1998 and annual data from 2000 through 2012, a total of 14 years of longitudinal data. Eight waves of biennial data were compiled directly from the HRS, and six living arrangement statuses assessed at the middle point between two biennial interviews were constructed. Using self-reported transition dates of respondents and their household members, the current study assessed respondents' living arrangement status at a hypothetical interview date interpolated between two biennial interviews. Because these self-reported dates were not available in 2000 and only available since 2002, the living arrangement status in 1999 between the 1998 and 2000 biennial interviews was left missing. The detailed process of constructing between-wave living arrangement status is documented in the Appendix A. The results show that

biennial data are less effective in capturing short-term living arrangements than the annual data. However, some very short-term living arrangement episodes, such as post-acute care institutionalization, may still be missed from the annual living arrangement data.

Living arrangement states

The four-state scheme of living arrangements is defined hierarchically by checking the following statuses at the time of biennial or between-wave pseudo interview dates accordingly:

1. Whether the respondent was alive
2. Whether the respondent was living in an institution
3. Whether the respondent was living with a spouse or partner
4. Whether the respondent was living with at least a child if not living with a spouse or partner
5. Whether he or she was living with at least one household member if not living with a spouse/partner or child

Living alone thus suggests that the respondent was alive, non-institutionalized, and the only person identified in the household at the time of interview date. In the current study, co-residence with someone was aggregated to include living with spouse or partner, children, or other persons due to limitations in the sample size of the study data. Note that living only with a spouse can suggest independence, whereas living with children or others may indicate dependency. In contrast to living alone, co-residence thus suggests a more complex state. Living alone, institutionalization, and death are defined the same as in the more disaggregated six-state scheme used in Chapter Two.

The proxy response from the HRS exit interviews was used as the primary source of information for determining mortality status. When the available National Death Index (NDI) report was different from the proxy response, the NDI mortality status was used. The most recent NDI match was conducted in 2008. Since the cross-sectional HRS mortality status variables are based on proxy reports, the mortality status was updated accordingly if a respondent's death record was matched by NDI. For nonrespondents whose mortality status was obtained via the NDI match, his or her mortality status was carried forward to the first annual interview date following the date of death, and the living arrangement statuses between the last valid interview and all annual interviews preceding the date of death were left as nonresponse.

Among the 10,357 community-dwelling respondents aged 65 and older at baseline, only 16 of them were missing the birth month in the HRS Tracker File. None of the respondents had a missing birth year. Five of the 16 respondents had birth month from the RAND HRS, and the remaining eleven respondents were assigned July, the middle of the year, as their birth month. For the date of death of deceased respondents, 6,103 had matching NDI records; 326 had dates of death reported by their proxy respondent; 69 were reported as having died by their proxy respondents without any information on their dates of death from either the Tracker file or the NDI. Their dates of death were imputed to be the middle point between their last available biennial interview dates and the beginning dates of the biennial interview in which they were identified as deceased.

Markov chains and interpolated Markov chain (IMaCh) approach

As multistate life tables rely on longitudinal data for calculating transition probabilities, the precise timing of transition event occurrence and the intervals of the survey interviews have been issues for estimation (Laditka & Hayward, 2003). Longitudinal studies rarely record the exact timing of transitions; instead, researchers have to infer a transition by comparing a respondent's status between interviews. The comparison clearly ignores potential transitions that occur between interviews. The often unequal survey intervals in longitudinal data compound the issue of identifying a transition. To address these issues, researchers treat observed statuses at interviews as described by an underlying stochastic process, operating in continuous time such as a Markov process (Land, Guralnik, & Blazer, 1994) or in discrete time such as a Markov chain (Laditka & Wolf, 1998; Lièvre, Brouard, & Heathcote, 2003; Wolf & Gill, 2009). Within this stochastic process, we are able to model unobserved transitions between observation intervals (Laditka & Wolf, 2009).

In the current study, the interpolated Markov chain (IMaCh) approach is used to estimate transition probabilities by recovering parameters of the embedded Markov Chain from discrete-time transition data (Laditka & Wolf, 1998; Laditka & Hayward, 2003; Lièvre, Brouard, & Heathcote, 2003). In the following methodology section, the discrete-time Markov chain is first introduced. Next, the specifications of IMaCh are discussed in detail. Finally, the life table functions that IMaCh calculates are described.

Discrete-time Markov Chain

The embedded Markov Chain is employed in IMaCh to model transitions from imprecise measurement of event times with longitudinal data. Although it is assumed that

only one state is observed during the time interval in the Markov chain, the model is able to exhaust potential transitions when the time interval approaches the minimum (e.g. a month). Let *X(x)* denote the state for an individual at age *x*. *X(x+h)* denotes the state after time *h* for the same individual. The conditional probability of being in state *k* at age *x+h* given the original state *j* at age *x* is:

$$ {}_h p_x^{jk} = \Pr\left(X\left(x+h\right) = k \mid X(x) = j\right) \qquad [3.1] $$

The four states of living arrangements are coded 1 for co-residence with someone, 2 for living alone, 3 for institutionalized, and 4 for deceased. The transition probabilities among these states are expressed in a 4×4 matrix,

$$ {}_h P_x = \left({}_h p_x^{jk}\right) = \begin{pmatrix} {}_h p_x^{11} & {}_h p_x^{12} & {}_h p_x^{13} & {}_h p_x^{14} \\ {}_h p_x^{21} & {}_h p_x^{22} & {}_h p_x^{23} & {}_h p_x^{24} \\ {}_h p_x^{31} & {}_h p_x^{32} & {}_h p_x^{33} & {}_h p_x^{34} \\ 0 & 0 & 0 & 1 \end{pmatrix} \qquad [3.2] $$

, where transition rates are arranged by the origin state *j* and destination state *k*. Each row *j* of the matrix indicates transition rates from an original living arrangement state at the beginning of the interval to corresponding column destination states *k* at the end of interval. Note that the specification of the last row vector indicates the absorbing nature of death. The transition rates are zero for transitions from death to three living states. The transition rate is one when both the origin and destination states are death.

Interpolating Markov Chain (IMaCh)

Based on Laditka and Wolf's pioneering work (1998) on embedded Markov chains, the IMaCh software was developed for estimating transition rates and multistate life tables from longitudinal survey (Brouard and Lièvre 2002; Lièvre, Brouard, &

Heathcote, 2003). In IMaCh, the transition probabilities shown in Equation [3.2] are estimated with multinomial logit, assuming that the dependence on age *x* is log-linear with a fixed time interval *h* (Cai & Lubitz, 2007; Laditka & Wolf, 1998; Wolf, Mendes de Leon, & Glass, 2007). The resulting transition rates are used as inputs for calculating multistate life table functions.

$$\ln \frac{{}_h p_x^{jk}}{{}_h p_x^{jj}} = \alpha_{jk}(h) + \beta_{jk}(h)x, \quad j \neq k \qquad [3.3]$$

Alternative estimation approaches used in other research include separate hazard models for each destination-specific transition, assuming that estimated destination-specific probabilities are independent of each other (Hayward & Grady, 1990; Crimmins, Hayward, & Saito, 1994) or the complementary log-log approach, a proportional-hazards model that provides estimated parameters invariant to the width of time intervals and allows multiple events occurring in the same time period (e.g. disabled and then died in the same month) (Wolf & Gill, 2009).

The time interval *h* does not necessarily correspond with the interview interval. The embedded Markov chain assumes that there may be as many as transitions taking the minimal time interval between interviews (e.g. up to 12 monthly transitions between annual interviews). To retrieve the parameters (e.g. for monthly transitions) that can describe the observed status at interviews (e.g. annual interviews), IMaCh transforms the transition probabilities using the minimal time interval to the transition probabilities matching the duration, *d*, between interviews by multiplying the transition matrix to the power of (*n-1)*, where *n* is the number of the maximal possible transitions between interviews (e.g. 11 transitions between exact annual intervals). Note that this

transformation also considers the age interval by setting age at the second interview of the interval to be $x_2 = x_1 + d$, where x_1 is age at the first interview, and the duration between interviews, d, equals $(n \times h)$. As the number of intervals is n, the number of transitions is $(n\text{-}1)$. When the duration between ages x_1 and x_2 is $(1 \times h)$ or n=1, the difference between age x_1 and x_2 require one transition. When the duration between ages x_1 and x_2 is $(2 \times h)$ or n=2, the difference between ages x_1 and x_2 requires two transitions, namely transitioning from initial age x_1 to age $x_1 + (1 \times h)$ and from initial age $x_1 + (1 \times h)$ to age $x_1 + (2 \times h)$. The product of the transition matrix expressed with initial age of the minimum time interval age $x_1 + ([n\text{-}1] \times h)$ and the number of transitions n within the duration is the transition probability of the period between interview ages x_1 and x_2 with a duration d between interviews for an individual:

$$\prod_{u=1}^{n} {}_{h}P_{x1+(u-1)h} = \left({}_{d}p_{x1}^{jk} \right) \qquad [3.4]$$

These interval transition matrices at a particular age of each individual contribute to the likelihood of observing the living arrangement status at interviews. If one is observed more than once, the contribution of the individual to the likelihood is the matrix product of the person's transition matrices at each age. For the deceased, the date of death must be known for the calculation of the contribution to the likelihood. Otherwise, a pseudo death date is assumed as at the mid interval. Finally, the log-likelihoods of all individuals are summed. The parameters in Equation [3.3] are estimated by maximizing the log-likelihood of the quantity. For more details, see Lièvre, Brouard, and Heathcote (2003).

The advantages of the IMaCh approach include simplifying inferential procedures, calculating standard errors of estimated parameters with a maximum likelihood method, and accommodating small units of an embedded Markov chain (such as a month) and thus being able to approximate a continuous time process (Lièvre, Brouard, & Heathcote, 2003).

IMaCh adopts the well-developed maximum likelihood approach for estimating the underlying parameter of expressing the probabilities of individual transitions (Laditka & Wolf, 1998; Laditka & Hayward, 2003; Lièvre, Brouard, & Heathcote, 2003). As the standard errors for the estimated parameters are obtained with the maximum likelihood method, IMaCh can further derive standard errors for transition rates and life expectancy (Lièvre, Brouard, & Heathcote, 2003), allowing the calculation of confidence intervals for subgroup comparisons.

Following the conceptualization of the embedded Markov chain, IMaCh allows more than one event occurring during a survey interval that may be widely spaced (See Laditka & Wolf, 1998; Wolf & Gill, 2009). The time unit of the embedded chain can be made as short as one month irrespective of the original survey intervals (Lièvre, Brouard, & Heathcote, 2003). Thus, the IMaCh is able to work with data of unequal intervals or different interval lengths, accommodate missing data at one or more interviews, and estimate potentially unobserved multiple transitions within an interval (Crimmins, Hayward, Hagedorn, Saito, & Brouard, 2009; Yong & Saito, 2012).

Similar to other Markov-based hazard modeling approaches that use longitudinal data for estimating transition probabilities (e.g. Hayward & Grady, 1990), IMaCh is able to smooth transition probabilities across ages because of its Markov model assumption

that the transition probabilities only depend on the state that an individual occupies at a particular age (Laditka & Hayward, 2003). Since IMaCh uses a logit-based estimation approach, which assumes that the transitions occur at the end of the interval, its results may differ from those from approaches that assume a transition occurring at the middle of the interval (Crimmins et al., 2009).

Studies that attempt to evaluate the embedded Markov chain approach offer insights as well as cautions. For accurate estimates of active and disabled life expectancy, it is considered sufficient to estimate from data with intervals of no more than two years (Gill, Allore, Hardy, Holford, & Han, 2005). A study comparing life expectancy estimates using the observed monthly transitions data with estimates using annual or biennial transitions derived from the same monthly data reports that individual parameters and estimated monthly transition rates derived from annual or biennial interval data are biased with respect to actual observed monthly rates. However, possibly due to offsetting biases, the difference between life expectancy estimates is only marginal (Wolf & Gill, 2009). The authors do not seem to offer a sound explanation for these biases other than suggesting that the disablement dynamics may not be Markovian, a theoretical ground upon which the present dynamic analyses have been based. Research with monthly data applied on dynamic processes is scarce. Empirical studies assuming a semi-Markov or non-Markov model are rare (Cai, Schenker, & Lubits, 2006). Even though these issues are substantial and could affect the precision of estimates of the embedded Markov chain, the goal of the present study of illustrating the relative differences of life table functions by gender and living arrangement status should not be affected.

Multistate Life Table Functions Calculated by IMaCh

IMaCh estimates transition probabilities directly from longitudinal data and uses them as inputs for calculating these multistate life table functions, including implied prevalence rates, population-based life expectancies for the overall population, and status-based life expectancies by initial states. Essentially, IMaCh estimates status-based life table measures. However, IMaCh is able to estimate implied prevalence rates—that are generally available from population-based life tables (Crimmins, Hayward, & Saito, 1994)—and population-based life expectancies irrespective of an initial state.

By definition, prevalence rates describe the living arrangement states of the life table population during the study period. The prevalence rates of a living arrangement are a resulting rate, indicating a stock of persons in the state at a given age, plus the net flows into and out of the living arrangement state over a period of time (Crimmins, Hayward, & Saito, 1994; Schoen & Woodrow, 1980). The prevalence implied by continuing the current transition and mortality rates may be different from the observed prevalence rate in a given time interval because the latter often masks the varying transition processes and changing mortality risks (Crimmins, Hayward, & Saito, 1994; Crimmins et al., 2009; Guillot, 2011; Lièvre, Brouard, & Heathcote, 2003). In IMaCh, the prevalence rate ${}_t w^{i1}(x)$ for all persons at age *x* in a particular state 1 is calculated from a cohort of persons in any state *i* at *t* years earlier. Based on destination-specific transitions rates between *t* years ago and the present age, the prevalence rate of state 1 is defined as:

$$ {}_t w^{i1}(x) = \frac{{}_t p^{i1}_{x-t}}{{}_t p^{i1}_{x-t} + {}_t p^{i2}_{x-t} + {}_t p^{i3}_{x-t}} \qquad [3.5] $$

Assuming three living states, the prevalence rates of age x in state 2 and 3 are ${}_t w^{i2}(x)$ and ${}_t w^{i3}(x)$, respectively. The three curves for the same age *x* converge to the same limit, which is the implied prevalence. The study uses implied prevalence instead of other terms of the same measure, such as stable prevalence and period prevalence—the latter appears in Lièvre, Brouard, and Heathcote (2003). This measure suggests the prevalence rates of a state at age *x* according to the original state of the cohort at age (*x*-*t*), calculated from the living arrangement transitions in the observation period of the longitudinal data.

IMaCh first calculates *status-based* state-specific life expectancy for each living arrangement state respective of an initial state, e_x^{ij}, directly from transition probabilities. Let e_x^{ij} denote the expected subsequent time spent in state *j* by an individual observed in state *i* at age *x* (Lièvre, Brouard, & Heathcote, 2003; Schoen, 1988). In this expression, the time interval *h* is suppressed by assuming *h* = 1, and *y* denotes a subsequent time. The mean of the subsequent time spent in state *j* by individuals in state *j* at age *x* is expressed as ${}_y p_x^{ij}$ (Lièvre, Brouard, & Heathcote, 2003). These are (*y, x*)-transition probabilities (Willekens, 1987) or state occupancy probabilities (Kuo, Suchindran, & Koo, 2008), indicating the probability that an individual is in state *j* at a specified time *y* given being in state *i* at time *x*. The expected length of time spent in a state is:

$$e_x^{ij} = \sum_{y=1}^{\infty} {}_y P_x^{ij} \qquad [3.6]$$

The same formula is adopted by Kuo, Suchindran, and Koo (2008) and Wolf and Gill (2009).

As a status-based life expectancy, the total life expectancy respective of a state at a given age indicates the total expected remaining life given being observed in the state at the given age, and it is simply the sum of these individual state life expectancies respective of the initial state at the corresponding age. For example, the life expectancy of living alone at age 65 is the sum of state-specific life expectancies, which an average person living alone at age 65 is expected to spend in living with someone, alone, and in an institution.

Next, before calculating population-based total life expectancy, IMaCh first calculates population-based state-specific life expectancy irrespective of an initial state ($e_x^{\cdot j}$) as the weighted average of the same conditional state expectancies for different initial states at a given age. It indicates the expected subsequent time spent in state *j* by an individual in all living states at age *x* (Lièvre, Brouard, & Heathcote, 2003; Schoen, 1988). For example, to calculate the life expectancy at age 65 for the entire population spent in living alone, IMaCh weights the life expectancy of living alone as being initially living with someone, alone, and in an institution by the proportions of the population at age 65 living with someone, alone, and in an institution, respectively.

IMaCh offers options of using weights from either the observed prevalence rates or the estimated implied prevalence rates. In IMaCh's terminology, life expectancy weighted by the implied prevalence is "status-based", whereas life expectancy weighted by observed prevalence is "population-based". In the current study, implied prevalence was chosen for weights.

The population-based total life expectancy at a given age is computed simply by adding state-specific life expectancies irrespective of an initial state at a given age. For

example, total life expectancy at age 65 is the sum of life expectancy at age 65 in living with someone, alone, and in an institution irrespective of an initial state. At the population level, we are able to evaluate the proportion of remaining expected life in each of the living arrangement states at a given age.

Analytic Plan

A person-level file containing interview dates and corresponding living arrangements status was prepared as required as an input file for the IMaCh. No imputation is needed, since IMaCh can handle data with unequal intervals and missing data. Note that the 1999 status is left as missing to take advantage of the IMaCh's strength. Terminal missing may not be an issue for longitudinal HRS data, because respondents are kept in the sample and followed until a death is reported or a request for exclusion from the sample is given. All the analyses using IMaCh were weighted using the person-level weights in 1998.

IMaCh was set to compute transition rates in an interval of one month. An important implication of using month as the time interval for the Markov Chain is the assumption of no transition occurring within the monthly interval. Within such a short period of time, it is unlikely to have more than one living arrangement transition. Prior research often used a 90-day cutoff to determine long-term vs. short-term institutionalization (Liu, McBride, & Coughlin, 1994; Muramatsu, Yin, Campbell, Hoyem, Jacob, & Ross, 2007). A recent multistate life table analysis also focused on long-term institutionalization that lasts for at least 90 days as comparable to community residence (Martikainen et al., 2014). Because of interval censoring, the study was unable to determine the length of institutionalization observed at biennial interviews. In other

words, the current study did not distinguish short-term vs. long-term institutionalization, and allows the duration of institutionalizations to be measured in months. The monthly interval specification ignores short-term post-acute-care institutionalizations that begin and end within a month, but it allows for institutionalizations with lengths longer than a month but shorter than three months.

Estimating transition probabilities by month suggests the estimated probabilities are probabilities of being observed in a particular state one month later, even though the time variable is termed "age". For example, the monthly transition probability of being observed in state 2 at age 70 and one month (70 and 1/12 years) is conditional on being observed in state 1 at age 70. As discussed above, during such a short period of time, multiple transitions are unlikely, so that this monthly probability is close to a monthly incidence rate, which is defined as the limit of the ratio of ${}_h p_x^{jk}$ to h, where h approaches zero. In particular, when $h = 1$ (e.g. one month), the monthly transition probability is equal to the monthly incidence rate. To illustrate changes in a year, this study presents annual quasi incidence rates, which are simply monthly rates multiplied by 12. This multiplication implies an additional assumption in which the monthly incidence rates are equal in each month of a year. These annual incidence rates differ from annual transition probabilities, which can be obtained by multiplying 12 monthly transition matrices. Nevertheless, the difference between annual incidence rates and annual transition probabilities may not be large, because it is expected that even over a year, monthly living arrangement transitions are rare.

Each transition probability was specified as the function of age only for each gender-specific model to ensure that diverse gendered patterns of living arrangement

transitions can be properly modeled. Due to sparse transitions out of an institution, the study did not include any other covariates.

Descriptive Statistics Observed from Sample Data

Table 3.1 describes the prevalence distributions of living arrangement status for men and women in the study sample in each year over the 14-year period except 1999. As discussed earlier, the 1999 status was not included in the current analysis. At the baseline in 1998, about 82% and 59% of men and women, respectively, were living with someone, while 18% and 41% of them were respectively living alone. The mortality prevalence rates for the baseline samples increased slightly faster among men than women over the observation period. By the last wave, 66% of men and 60% of women had died. In 2012, about 21% and 7% of men in the baseline sample were living with someone and alone, respectively. In contrast, about 15% of women in the baseline sample were living with someone, and another 15% of them were living alone in 2012.

Table 3.1.1. Men's Observed Percentage Distribution of Living Arrangement Status in Biennial and Pseudo Between-wave Years

Year	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Co-residence	82.1	67.6	60.6	56.8	52.1	49.0	44.0	41.2	36.8	34.3	29.3	26.2	22.5	21.1
Alone	17.9	15.9	14.4	14.1	12.0	12.0	10.6	10.7	9.8	9.3	7.8	7.7	6.8	6.8
Institution	0.0	1.3	1.7	2.0	2.3	2.1	2.5	2.2	2.6	1.8	2.1	2.0	2.2	1.8
Died	0.0	10.5	16.4	21.8	26.6	31.0	36.1	40.7	44.7	49.2	54.1	59.0	62.9	65.9
Missing	0.0	4.6	6.9	5.3	7.1	5.9	6.8	5.2	6.2	5.4	6.7	5.1	5.7	4.4

Note: Weighted percentage, N=4,444.

Table 3.1.2. Women's Observed Percentage Distribution of Living Arrangement Status in Biennial and Pseudo Between-wave Years

Year	1998	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Co-residence	58.8	48.2	42.4	40.3	36.2	34.5	30.2	28.5	24.8	23.5	19.6	18.1	14.1	15.0
Alone	41.2	37.4	34.6	33.6	30.0	29.5	27.0	26.5	24.2	23.2	19.5	18.2	15.8	15.3
Institution	0.0	3.0	3.6	4.0	4.6	4.5	4.6	4.4	5.0	4.4	4.7	4.6	4.4	4.4
Died	0.0	6.8	11.7	16.2	20.7	25.1	29.4	34.0	38.3	42.8	47.9	53.1	56.9	59.5
Missing	0.0	4.5	7.7	5.9	8.5	6.5	8.9	6.5	7.7	6.2	8.4	6.0	8.8	5.9

Note: Weighted percentage, N=5,913.

Table 3.2 shows gender distributions of all annual living arrangement transitions made over the study period. For men, about 70% of their pre-mortality transitions were remaining in a co-residence living arrangement with someone else. Alternatively, only 44% of pre-mortality transitions for women were classified as continued co-residence. As a much higher percentage of women were living alone at baseline than men at baseline, the percentage of transitions classified as remaining living alone are 16% for men and 38% for women. Due to the apparently great stability of living arrangements among older persons, percentages for other types of annual transitions were generally low, but gender differences were distinct as well. A higher percentage of annual transitions made by women involved entering an institution from living alone (1.7%) and remaining institutionalized (3.9%) during the interval than the respective percentages of 0.7% and 1.7% for their male counterparts. While the percentage of transitioning from co-residence to death was higher among men (4.9%) than women (2.6%), the percentage of transitioning from living alone and in an institution to death was higher among women (2.3% and 3.9%) compared to men (1.8% and 1.2%).

Table 3.2. Distribution of Living Arrangement Transitions between Intervals

	Men		Women	
	N	%	N	%
Remained co-residence	23,358	69.7	21,842	44.0
Co-residence to living alone	659	2.1	1,322	2.7
Co-residence to institutionalized	298	0.9	499	1.0
Died from co-residence	1,729	4.9	1,287	2.6
Living alone to co-residence	299	1.0	761	1.6
Remained living alone	4,815	15.8	16,557	37.9
Living alone to institutionalized	216	0.7	753	1.7
Died from living alone	546	1.8	1,027	2.3
Institutionalized to co-residence	53	0.2	96	0.2
Institutionalized to living alone	34	0.1	162	0.4
Remained institutionalized	574	1.7	1,844	3.9
Died from institutionalized	405	1.2	836	1.8
Total	32,986	100.0	46,986	100.0

Note: Weighted percentage, unweighted N. Transitions from or to a missing status are not included. Transitions of remaining in the absorbing mortality state are excluded.

Multinomial Logit Empirical Results

Estimated parameters used to calculate transition rates are shown in Table 3.3. Relative to staying in one of the three initial living arrangements, the probability of living arrangement transitions generally increased with age, except for few transitions of which the probability was negatively associated with age. Relative to continued co-residence, the risk of transitioning from co-residence to living alone was 7% higher ($\exp^{0.071}$= 1.074) for men with each year of increase in age. The corresponding risks for men transitioning to an institution and dying were 15% higher ($\exp^{0.143}$= 1.154) and 10% higher ($\exp^{0.091}$= 1.195), respectively, for each year of increase in age. The respective odds for women were 3%, 13%, and 11% higher for transitioning to living alone, in an institution, and death, respectively, than odds of staying in co-residence.

For men and women, the probability of transitioning from living alone to co-residence declined with age, although it was not statistically significant. However, the

risk of entering an institution from living alone relative to remaining living alone was 11% higher for men ($\exp^{0.107}$=1.113) and 14% higher for women ($\exp^{0.132}$=1.140) for each increase in age.

Table 3.3.1. Estimated Parameters of Living Arrangement Transitions for Men Aged 65 and Older

Origin State	Destination State	Variable			
		Constant	Standard Error	Age	Standard Error
Co-residence	Living Alone	-11.678+	0.490	0.071+	0.006
Co-residence	Institutionalized	-18.209+	0.837	0.143+	0.010
Co-residence	Died	-12.612+	0.344	0.091+	0.004
Living Alone	Co-residence	-5.269+	0.650	-0.001	0.008
Living Alone	Institutionalized	-14.287+	0.802	0.107+	0.009
Living Alone	Died	-8.100+	0.658	0.037+	0.008
Institutionalized	Co-residence	-1.090	1.837	-0.049+	0.022
Institutionalized	Living Alone	-7.982+	2.262	0.029	0.026
Institutionalized	Died	-7.449+	0.680	0.050+	0.008

Note: Estimates are based on weighted data. $^{+}$ indicates z-statistics greater than 1.96.

Table 3.3.2. Estimated Parameters of Living Arrangement Transitions for Women Aged 65 and Older

Origin State	Destination State	Variable			
		Constant	Standard Error	Age	Standard Error
Co-residence	Living Alone	-7.311+	0.332	0.025^{+}	0.004
Co-residence	Institutionalized	-15.969+	0.529	0.121^{+}	0.006
Co-residence	Died	-13.655+	0.352	0.100+	0.006
Living Alone	Co-residence	-5.447+	0.461	-0.003	0.006
Living Alone	Institutionalized	-16.432+	0.490	0.131+	0.018
Living Alone	Died	-12.221+	0.506	0.079+	0.013
Institutionalized	Co-residence	2.005+	1.544	-0.089+	0.006
Institutionalized	Living Alone	-2.524	1.095	-0.029+	0.004
Institutionalized	Died	-6.362+	0.501	0.032+	0.006

Note: Estimates are based on weighted data. $^{+}$ indicates z-statistics greater than 1.96. The reference states for transitions are staying in the same state.

The probability of exiting institutions for co-residence significantly declined with age for both men and women. For each additional year in age, the risk of exiting an institution to living with someone was 5% lower ($exp^{-0.049}$=0.952) for men and 8% lower ($exp^{-0.089}$= 0.915) for women relative to otherwise similar persons who made no transition from the institution. While men's probability of exiting institutions for living alone did not appear to vary with age—a non-significant result—women's probability of exiting institutions for living alone significantly declined with age. For women, each increase in age raised the probability of death by 3% ($exp^{0.032}$= 1.033) relative to continued institutionalization, but it reduced the probability of transitioning to living alone by 3% ($exp^{-0.029}$= 0.971) relative to continued institutionalization.

Since the multistate life table functions are based on transition probabilities estimated from longitudinal data, it is necessary to validate their precision by comparing them with vital statistics estimates for the entire population, such as the total life expectancy calculated by the National Center for Health Statistics. Table 3.4 shows that the estimated total life expectancy at selected ages was very close to the vital statistics reported by the National Center for Health Statistics. At age 65, total life expectancy from survey estimates for both genders was slightly higher than that from the vital statistics. The marginally higher estimates of total life expectancy may be possibly related to the exclusion of the institutional population in the baseline study sample (See Crimmins et al., 2009). Estimates at each given age were calculated from survivors at the age. Because baseline institutionalized persons were less likely to survive to older old ages, estimates for older ages were less deviant from vital statistics. The difference decreased at older ages, which supports the validity of the estimated results.

Table 3.4. Comparison of Total Life Expectancy between Vital Statistics and Survey Estimates by Sex

Age	Male		Female	
	Vital Statistics (2005)	Survey (1998-2012)	Vital Statistics (2005)	Survey (1998-2012)
65	16.9	16.99 (16.19-17.79)	19.6	19.98 (19.22-20.74)
75	10.4	10.43 (10.08-10.77)	12.3	12.42 (12.10-12.74)
85	5.5	5.71 (5.49-5.92)	6.6	6.76 (6.57-6.94)

Note: Vital statistics of total life expectancy are retrieved from revised tables based on Arias, Rostron, & Tejada-Vera (2010) at http://www.cdc.gov/nchs/data/dvs/LEWK3_2005.pdf.

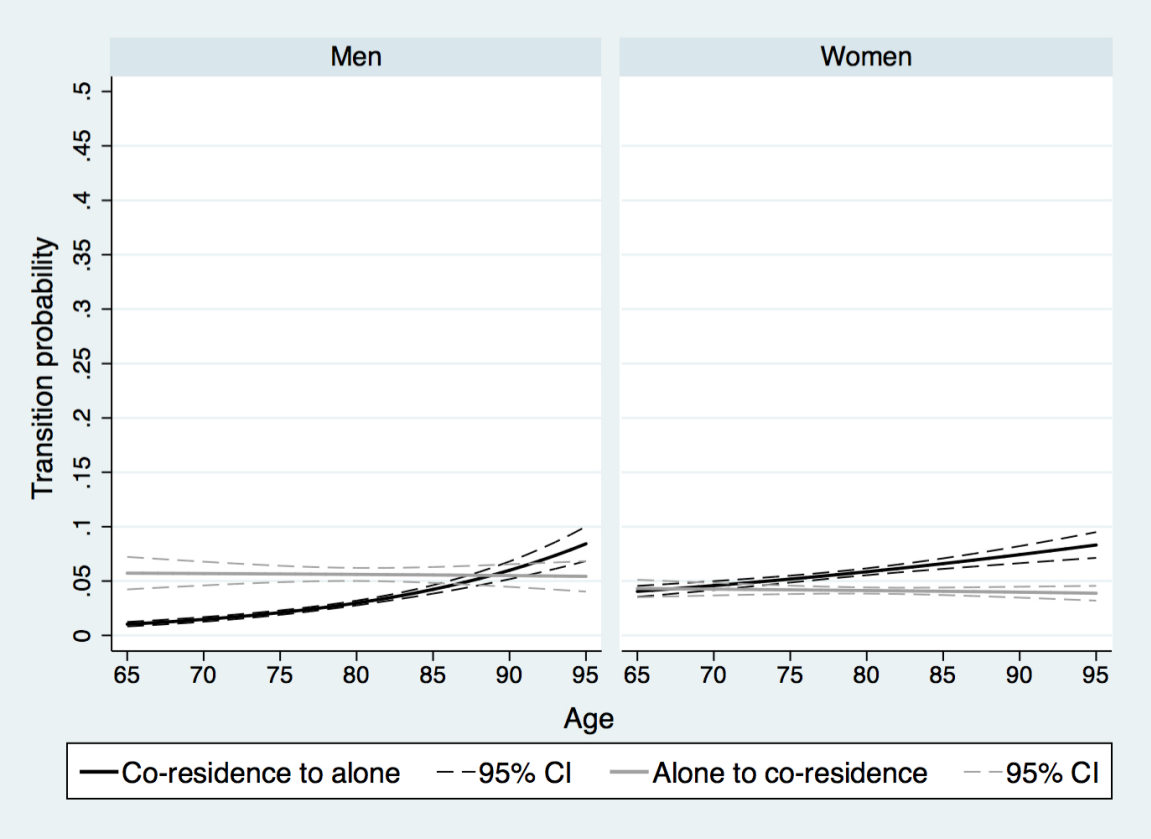
Multistate Life Table Results

The study results are discussed in the following order. First annual quasi incidence rates of transitions among three pre-mortem living arrangement states and one absorbing state (death) are discussed in order of (1) transitioning between co-residence and living alone, (2) entering an institution from co-residence and living alone, (3) exiting an institution to co-residence and living alone, and (4) dying from three respective living arrangements. Second, implied prevalence of three living arrangements is discussed as the life table population suggests. Third, population-based life expectancy at selected ages is discussed with state-specific life expectancies irrespective of an initial state that are shown for illustrating the distribution of average life time in three living arrangements. Fourth, status-based life expectancy is described by initial living arrangement at selected ages to show the differences in life expectancy based on one's living arrangement at the given ages.

Annual Incidence Rates of Transitions

Older persons' living arrangements are stable in general, but this does not suggest the transitions in living arrangements always remain the same. Figure 3.2 shows how estimated transition rates between co-residence and living alone and vice versa vary by age and gender. Ninety-five percent confidence intervals are shown with dashed lines. Despite very low rates and subtle age patterns, older old persons were more likely to make a transition from co-residence to living alone than their younger counterparts. In contrast, the rates of transitioning from living alone to living with someone barely changed with age. These age patterns may be attributable to grouping living with spouse, children, or others into a single co-residence category.

Figure 3.2. Estimates of Age-Specific Rates of Transitioning between Co-residence and Living Alone by Gender



Transition rates for men from co-residence to living alone were very low at age 65 years but increased faster with age than rates for women, whereas those same respective rates for women appeared to increase with age at a constant rate. Transition rates between co-residence and living alone appeared to differ by gender and age. At younger ages, men were more likely to transition from living alone to co-residence than the opposite direction. The difference disappeared at oldest old ages. At older old ages, women's transition rates between living alone to co-residence were lower than for the other direction.

Figure 3.3. Estimates of Age-Specific Rates of Transitioning from Co-residence and Living Alone into Institutions by Gender

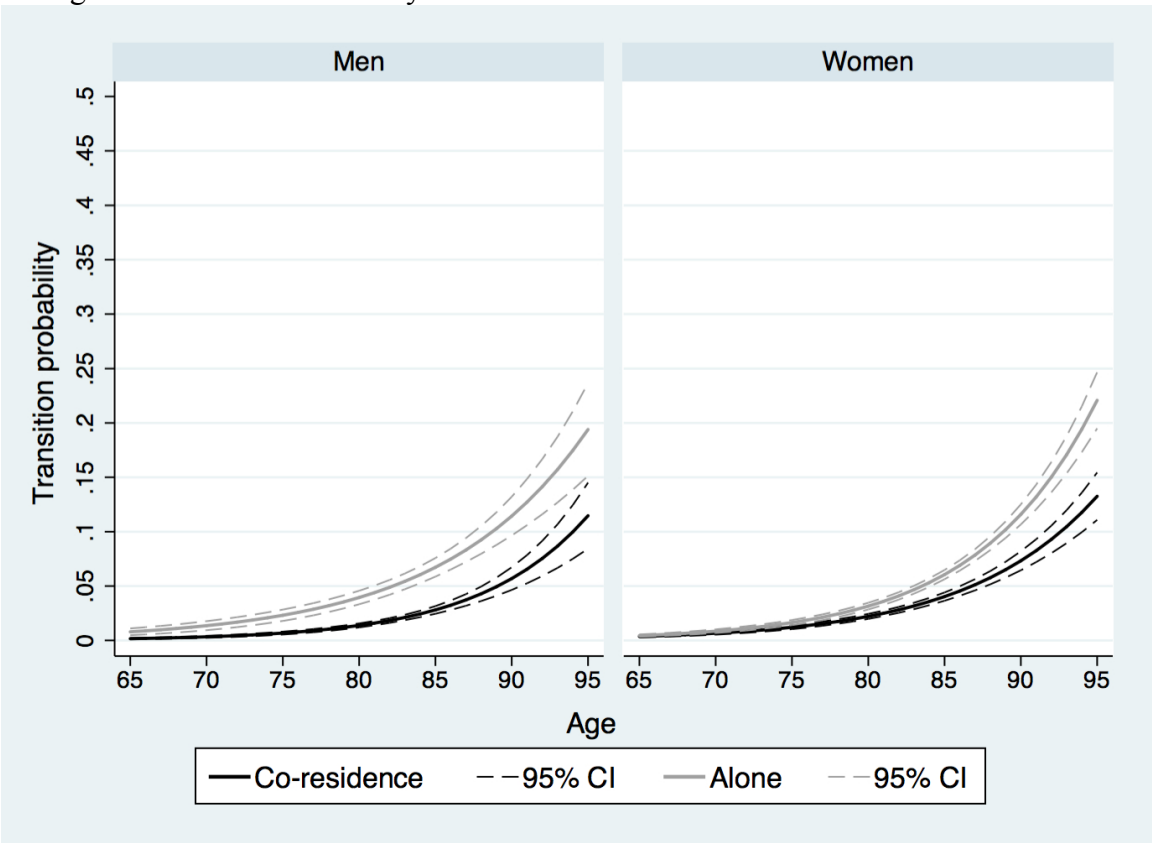


Figure 3.3 displays the estimated age-specific rates of entering an institution from co-residence and living alone, respectively, for men and women. Older persons' risks of institutionalization increased exponentially with age, especially for those at oldest old ages. In particular, the risks were significantly higher among men and women who were living alone than those who were co-residing with someone at all ages. The gap for men appeared at younger ages and remained intact into oldest old ages, whereas for women, the difference emerged roughly by age 80.

Figure 3.4. Estimates of Age-Specific Rates of Transitioning out of Institutions to Co-residence and Living Alone by Gender

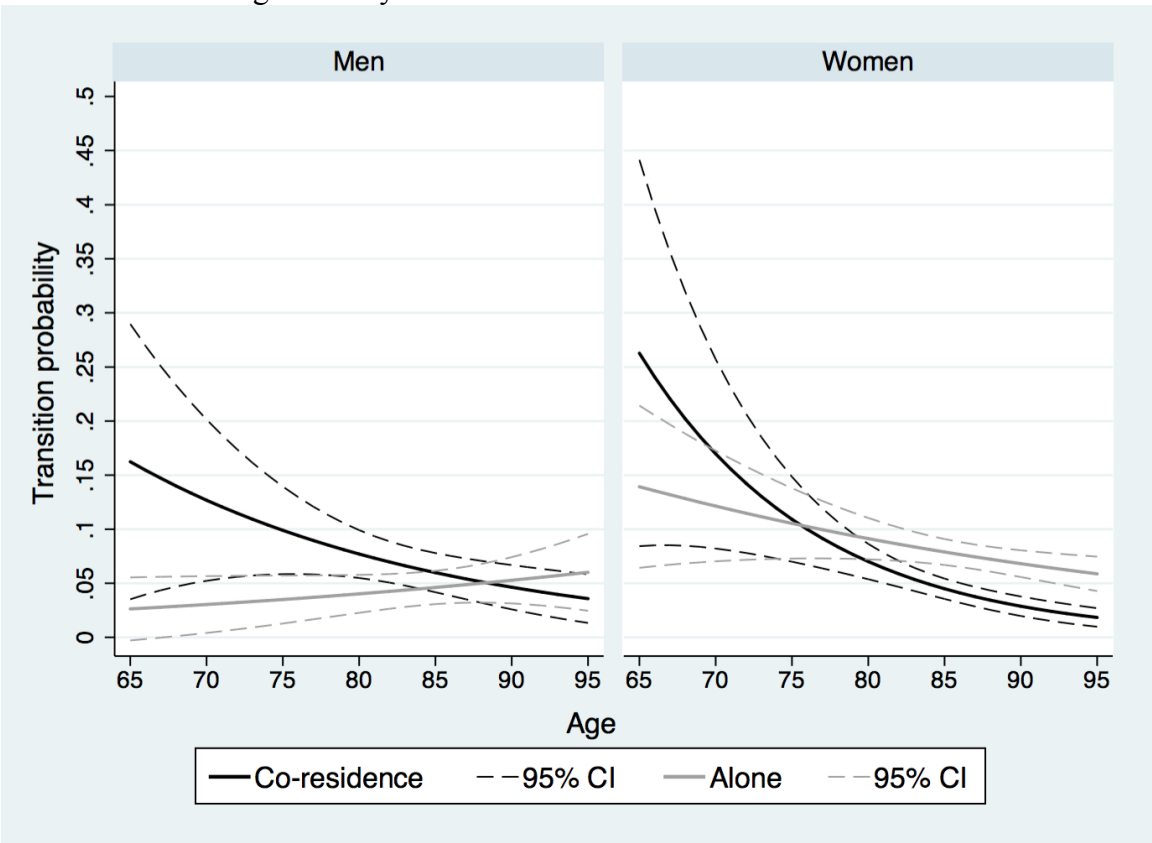
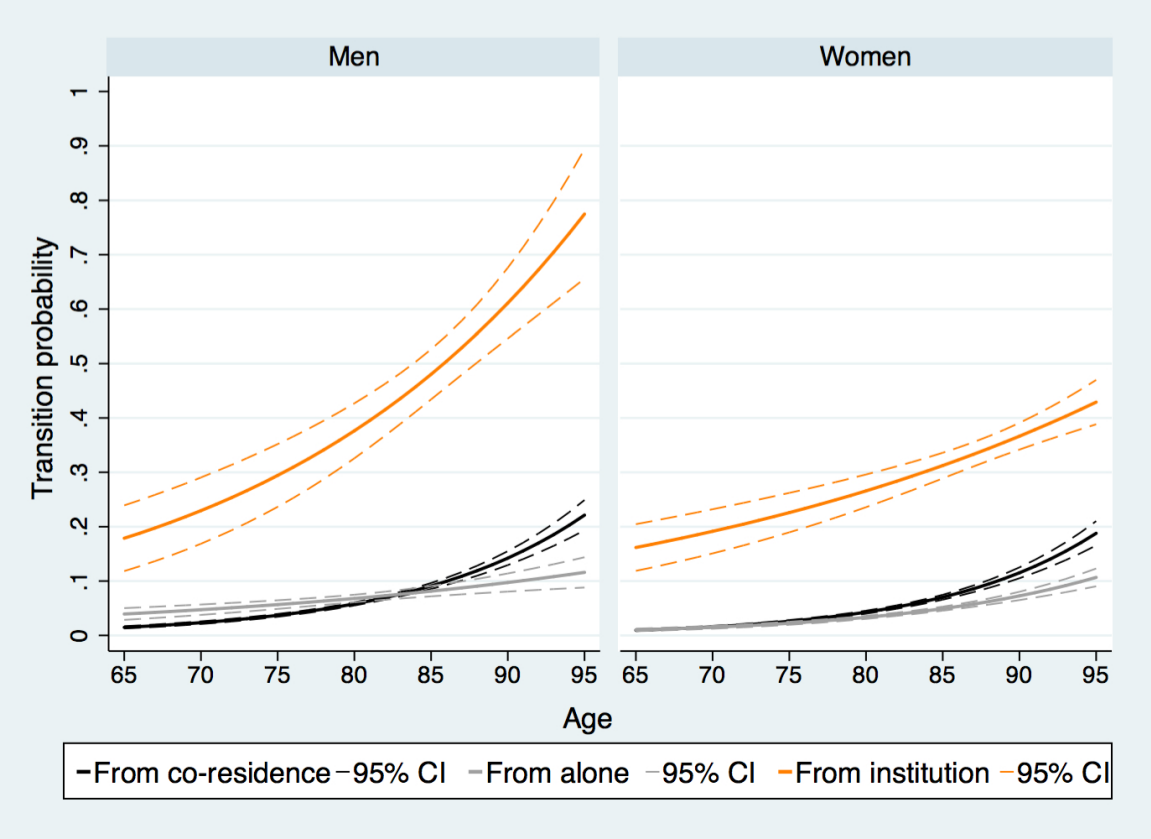


Figure 3.4 contains the rates for institutionalized men and women transitioning back to co-residence with someone or living alone. For both men and women, the age-

specific rates of exiting an institution to co-residence with someone rapidly declined with age along with largely shrinking wide confidence intervals. While men at older old ages had somewhat higher rates of transitioning from an institution to living alone relative to younger men, women's transition rates to living alone declined with age. Prior to age 80, men who exited an institution were more likely to live with someone than to live alone, even with very large confidence intervals. After age 80, women discharged from institutions were more likely to live alone than to subsequently co-reside with someone. As women had generally lower mortality rates while living in an institution than men, the declining discharge rates—either to co-residence or living alone—for women suggest that women tend to stay in institutions longer than men at the oldest old ages.

Figure 3.5. Estimates of Age-Specific Rates of Dying during Three Living Arrangements by Gender



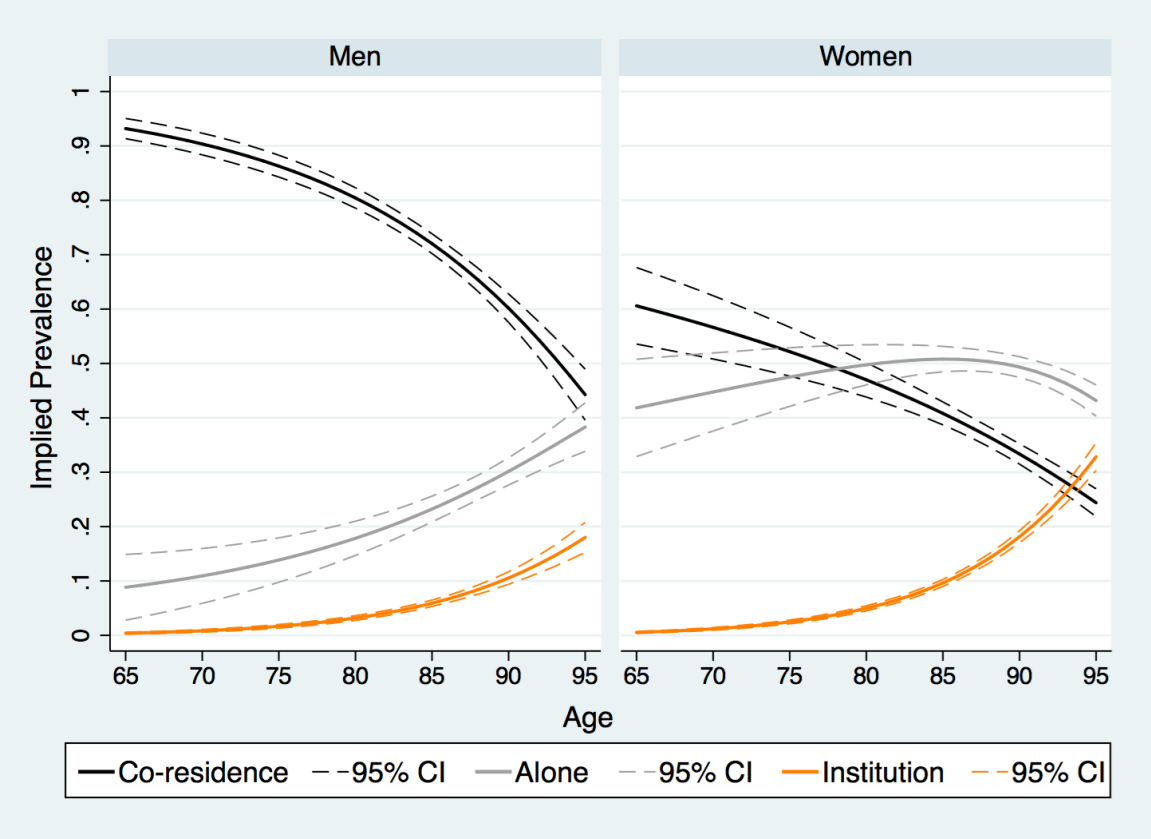
Age-specific mortality rates during co-residence, living alone, and institutionalization states are shown in Figure 3.5. The probability of dying was clearly highest during the institutionalization state, particularly for men at the oldest old ages. For men, the mortality difference at younger ages between co-residence and living alone was marginal but statistically significant; the probability of dying during the two living arrangements were almost identical for women at younger ages. At older ages, the mortality risks during living alone were lower than risks during co-residence for both men and women, beginning roughly at age 90 for men and age 85 for women.

The subtle yet differential age patterns of transition rates between living alone and living with someone—such as a spouse or a child—shown above generally correspond to the patterns found by Wilmoth (1998), namely similar positive rates of transitioning from living with a spouse or a child to living alone, and a negative association between age and rates of transitioning from living alone to living with a spouse or a child. With respect to transitions in and out of institutions and death during community-based living arrangements, the above results generally coincide with findings from Martikainen and colleagues (2014). Note that mortality rates in institutions are substantially higher than the estimates of Martikainen and colleagues (2014). This may be due to the inclusion of short-term institutionalization in this study, which may be linked to end of life care (Kelly, Conell-Price, Covinsky, Cenzer, Chang, Boscardin, & Smith, 2010). In short, transition rates estimated by IMaCh are in general in agreement with findings from early research. The low transition rates indicate that older persons tend to sustain their living arrangements with variations conditional on the current state they occupy and gender.

Implied prevalence

Figure 3.6 contains the prevalence rates of three living arrangements states in the life table population implied by the continuing rates of transitions among defined states. As it was shown earlier that transition rates and mortality during co-residence increased with age, and transition rates to co-residence decreased with age (Figure 3.2, 3.4, and 3.5), the implied prevalence of co-residence with someone for both men and women declined with age. The prevalence of co-residence was higher among men than women at younger ages. Even though the rate of declining prevalence in co-residence with age was faster among men than women, there was still a higher prevalence of co-residence with someone among the oldest old men than women.

Figure 3.6. Implied Prevalence of Co-residence, Living Alone, and Institutionalization by Gender



Men's prevalence of living alone increased with age; women's prevalence of living alone increased modestly at the beginning and started to decline around age 85. For men, the increasing transition rates from both co-residence and institution to living alone (Figures 3.2 and 3.4) might be the driving force for the higher prevalence of living alone among men at the oldest old ages. Given the similar age patterns of transition rates in and out of living alone for both genders, women's declining rates of exiting an institution to living alone with age (Figures 3.2 and 3.4) may contribute to the turning point of women's lower prevalence of living alone at oldest old ages. This decline coincided with rapidly increased prevalence of institutionalization beginning at about the same age (Figure 3.3). Despite the rise in men's prevalence rates of living alone with age and the decline in women's prevalence with age, there was still a higher prevalence of living alone among women than men at the oldest ages.

The increasing prevalence of institutionalization with age for both genders may be associated with three age-related patterns of transition rates: (1) rapid increase in admission rates to institutions (Figure 3.3); (2) declining discharge rates from institutions, even though the rates of transitioning to living alone for men slightly increased with age (Figure 3.4); and (3) very high mortality rates during institutionalization at advanced age, particularly for older men (Figure 3.5). In other words, although the probability of entering an institution increases with age, the rates of exiting the institution to co-residence or living alone did not appear to be high. Instead, elevated mortality rates among institutionalized persons, particularly men, may be the underlying cause of their low prevalence of institutionalization.

One way to understand the implications of continuing rates in the longer run is to examine the ages at which certain levels of prevalence occur. Men's prevalence of living alone did not reach 40% at any age, and women's prevalence of living alone was never lower than 40% at any age. The prevalence of living alone for women reaches 50% at roughly age 80, whereas the rate for men at the same age was still under 20%. The prevalence of institutionalization increased with age for both genders. Note that the study excluded respondents institutionalized at baseline. The prevalence of institutionalization was generally lower than 1% until roughly age 85 for women and age 90 for men. The prevalence of living in an institution reached 2% for women aged 90.

Figure 3.6 shows that the prevalence of co-residence decreased with age for both genders. The prevalence rates of co-residence for women are substantially lower than for their male counterparts at all ages. Whereas prevalence rates of living alone for men steadily increased with age, the rates for women increased modestly at younger old ages, and after reaching a peak at about age 85, the rates then decreased at older old ages. Prevalence rates of living alone were higher for women than for their male counterparts at all ages. The prevalence of institutionalization was low until older old ages for both genders, particularly for men. In general, living with someone was the most prevalent living arrangement for men throughout their life at old ages. In contrast, whereas living with someone was the dominant living arrangement for women at relatively younger ages, living alone became the most prevalent living arrangement for women by age 80.

Population-based life expectancy

Total life expectancy and state-specific life expectancy are calculated from age-specific transition rates. At each age, the total life expectancy is composed with three weighted state-specific life expectancies that are irrespective of initial states: life expectancy of living with someone, alone, and in an institution. Each of three weighted state-specific life expectancies is calculated from state-specific life expectancies respective of an initial state based on the living arrangement distribution in the life table population at a given age. For men at age 65, total life expectancy was 16.99 years: about 14.01 years spent in living with someone, 2.49 years spent in living alone, and 0.49 years spent in an institution. For women of the same age, the total life expectancy was 19.98 years. With a longer total life expectancy than their male counterparts, women of age 65 were expected to spend a shorter time in living with someone (9.68 years), but should spend a much longer time living alone (9.15 years) and in an institution (1.15 years).

Table 3.5. Total and State-Specific Life Expectancy by Age and Gender

Age	Total Life Expectancy	Living with Someone	Living Alone	Institution	% in Alone	% in Institution
Men						
65	16.99 (16.19-17.79)	14.01 (13.56-14.46)	2.49 (1.89-3.09)	0.49 (0.43-0.54)	14.7	2.9
75	10.43 (10.08-10.77)	7.80 (7.56-8.03)	2.10 (1.82-2.38)	0.53 (0.48-0.59)	20.1	5.1
85	5.71 (5.49-5.92)	3.45 (3.27-3.63)	1.65 (1.49-1.81)	0.60 (0.53-0.66)	29.0	10.5
Women						
65	19.98 (19.22-20.74)	9.68 (8.92-10.44)	9.15 (8.05-10.25)	1.15 (1.07-1.24)	45.8	5.8
75	12.42 (12.10-12.74)	5.21 (4.91-5.52)	5.98 (5.56-6.39)	1.23 (1.15-1.31)	48.1	9.0
85	6.76 (6.57-6.94)	2.21 (2.08-2.34)	3.20 (3.05-3.36)	1.34 (1.24-1.43)	47.4	19.8

Note: Confidence intervals are shown in parentheses.

For both men and women, total life expectancy declined with age as shown in Table 3.5. However, women were expected to have a longer life at all ages than men and to spend longer time, on average, living alone or in an institution than their male counterparts. While the percentage of men's life expectancy spent living alone was higher among those who were older, women were expected to spend nearly half of their average remaining life living alone at all three ages. In particular, women were also expected to spend twice as large a percentage of lifetime in institutions as men. Also the percentages of remaining lifetime spent in institutions for women were twice as large as for men. For women who survive to age 85, they were expected to spend 47% and 20% of their remaining life in living alone and in an institution, respectively.

The above results for population-based life expectancies and percentages of life expectancy living alone and in institutions are similar to findings of Martikainen and colleagues (2014) based on monthly institutionalization data from Finland. However, even though the current study potentially included short-term institutionalizations, the estimates and percentages of life expectancy in institutions are consistently lower on a comparable scale than Martikainen and colleagues' findings. The Finnish study is more inclusive in defining long-term care institutions—such as hospitals, health centers, and rehabilitation care—is chaining the broader spectrum of long-term care received in different institutions, and, most importantly, is based on the welfare state regime that offers more comprehensive long-term care support and services than in the United States. Given the dramatic differences between the Finnish and U.S. health care systems, it is not possible to make direct comparison. However, the fact that the estimates and percentages

of life expectancies in institutions are close enough to the Finnish results offers some confidence in the current results.

The findings for population-based life expectancy suggest that older women not only tend to live in a single-person household, but they also spend almost half of their expected remaining lifetime in the solitary state. In addition, life expectancy in institutions remains a significant part of older women's life into advanced ages. These unique experiences inevitably shape women's life course in ways that are very different from men's. Given that population-based life expectancy summarizes the overall experience of individuals in the life table population, one important question is whether these unique life course experiences of living arrangements are the same for those occupying different living arrangement states at a given age. The next section addresses this issue with an examination of status-based life expectancy.

Status-based Life Expectancy

To understand the long-term implications of being at a particular living arrangement at a particular age, we turn to examine status-based life expectancy. Status-based life expectancy indicates life expectancy based on a particular state at a given age, assuming all the transition rates remain the same. Status-based life expectancy is particularly useful for examining living arrangements, which tend to be relatively stable. As older persons reach older ages in different living arrangement states, status-based life expectancy provides measures of average remaining life differentiated by living arrangement at those ages.

As shown in Table 3.6.1, status-based life expectancy for men initially living with someone at age 65 was 16.8 years, 14.5 years living with someone, 1.9 years being alone,

and 0.5 years in institutions. Men who survived to age 65 and were living alone at the time were expected to live an additional 14.3 years in total, with 5.1, 8.6, and 0.6 years spent in co-residence, alone, and institutional living arrangements, respectively. Men who were institutionalized at age 65 were expected to live an additional 9.5 years in total, with 5.4, 1.3, and 2.8 years spent in co-residence, alone and institutional living arrangements.

At all ages, status-based life expectancies among community resident men were substantially longer than life expectancy of their institutionalized counterparts. The difference in life expectancies for men initially living with someone from that for those living alone decreased with advancing age. The differences in men's life expectancy between the two living arrangements were 2.6 years and 1.1 years at ages 65 and 75, respectively. Both differences were statistically significant, as the confidence intervals did not overlap. At age 85, there was no statistically discernable difference in life expectancy for men living with someone versus living alone.

The percentage of life expectancy spent in living alone among men initially living with someone increased modestly at older old ages, but not to the extent of the percentage of life spent living alone among those initially living alone. Older men who are living with someone at ages 65, 75, and 85 years old were expected to spend 11.0%, 13.3%, and 15.3%, respectively, of their expected remaining life spent living alone. For men living alone at age 65, 75, and 85, these same percentages of their remaining life spent living alone were 60.3%, 67.9%, and 72.9%, respectively. In addition, relative to men initially living with someone, these higher percentages of expected time spent in living alone were accompanied by relatively higher percentages of expected time spent in institutions, namely 4%, 7%, and 12% for age 65, 75, and 85, respectively. While older persons tend

to remain in their living arrangements, older persons living alone at given ages were expected to spend a much larger amount of remaining life living alone and in institutions.

Life expectancy for men living in an institution was shortest among the three status-based life expectancies at all ages. However, the institutional life expectancy becomes more significant among those who were institutionalized at older old ages. Men being institutionalized at age 65 were expected to spend 30.0% of their remaining life in institutions. For institutionalized men at ages 75 and 85, these percentages increased rapidly to 48.6% and 67.4%, suggesting that even among those who survived to advanced ages, being in an institution at that age was associated with an even longer residence in the institution relative to the younger institutionalized persons.

The above results for men suggest that living alone is associated with shorter length of expected life until advanced ages. In particular, for men who reach the oldest old ages and continue living alone, they not only have life expectancy that does not differ statistically from that for men living with someone at the same age, but also are expected to spend more time living alone and in institutions.

Table 3.6.1. Men's Status-Based Life Expectancy by Age and Three Initial Living Arrangement States

Age	Initial Status	Total (CI)	Not Living Alone (CI)	Living Alone (CI)	Institution (CI)	% in Living Alone	% in Institution
65	Not Alone	16.84 (16.47-17.21)	14.53 (14.18-14.88)	1.85 (1.69-2.01)	0.46 (0.41-0.50)	11.0	2.7
	Alone	14.25 (13.44-15.06)	5.10 (4.42-5.78)	8.59 (7.89-9.29)	0.56 (0.47-0.65)	60.3	3.9
	Institution	9.46 (7.11-11.80)	5.35 (2.87-7.83)	1.28 (0.71-1.85)	2.83 (2.05-3.61)	13.5	30.0
75	Not Alone	10.48 (10.26-10.71)	8.62 (8.43-8.81)	1.39 (1.28-1.50)	0.47 (0.43-0.52)	13.3	4.5
	Alone	9.41 (9.07-9.75)	2.37 (2.16-2.58)	6.39 (6.09-6.69)	0.65 (0.58-0.72)	67.9	6.9
	Institution	4.76 (4.09-5.43)	1.70 (1.21-2.19)	0.74 (0.48-1.00)	2.31 (2.01-2.62)	15.6	48.6
85	Not Alone	5.84 (5.61-6.06)	4.47 (4.29-4.66)	0.89 (0.78-1.00)	0.47 (0.41-0.53)	15.3	8.0
	Alone	5.82 (5.55-6.12)	0.89 (0.76-1.01)	4.25 (4.00-4.50)	0.69 (0.61-0.78)	72.9	11.9
	Institution	2.47 (2.25-2.70)	0.42 (0.31-0.54)	0.38 (0.28-0.49)	1.67 (1.53-1.80)	15.5	67.4

Note: Confidence intervals are shown in parentheses.

While men initially living with someone have the longest life expectancy relative to living alone or institutionalization until advanced ages, initially living with someone for women did not indicate a longer life, on average, than other living arrangements. Women living with someone and living alone at age 65 were expected to have almost identical life expectancy (19.4 years vs. 19.5 years), whereas women being institutionalized at the same age were expected to live for 14.1 years on average, about 5.3 years shorter than women living with someone or alone. Women living alone at ages 75 and 85 were expected to live an additional 12.4 and 6.8 years, respectively, about 0.3 and 0.4 years longer than women initially living with someone at the corresponding ages even though the difference was not statistically significant. Life expectancy for women in an institution at ages 75 and 85 was about 5 and 3 years shorter than those of women living with someone or alone.

Unlike men initially living with someone, who had modestly increased percentages of expected life spent in living alone, these percentages for women initially living with someone declined from 29% at age 65 to 20% at age 85. Unlike men, who had higher percentages of expected time spent living alone at older ages, the percentages for women initially living alone did not appear to vary by age and remain around 70% regardless of age. However, women in both initial states were expected to spend a considerable amount of their subsequent life in institutions. Life expectancy in institutions did not appear to differ among women who initially are living with someone or alone at selected ages. In addition, the percentage of lifetime spent in institutions was similar for women initially living with someone and women living alone. These findings

suggest that institution life expectancy did not appear to differ between women initially living with someone and those initially living alone.

Following the finding about the substantial time spent living alone among women initially living with someone, note that these percentages declined with age—a pattern that is completely the opposite of that found for older men. These declining percentages with age were accompanied by an expansion of the percentage of expected remaining life in institutions at older ages, resulting in a relatively stable distribution of expected lifetime living alone and in both institutions for women at older ages. For example, the percentage of women living alone or in an institution was 34.5% at age 65 (28.9% living alone; 5.6% in an institution), 34.6% at age 75 (25.7% living alone; 8.9% in an institution), and 35.2% at age 85 (19.9% living alone; 15.3% in an institution). Women initially living with someone were expected to spend slightly more than a third of their remaining lifetime living alone or in an institution regardless of age.

Being observed in an institution at a given age suggests health conditions that require intensive care. Similar to men, women in institutions are expected to live shorter lives than women initially living with someone or alone regardless of age. Also similar to men, even higher percentages of subsequent life spent in institutions are found among women at older old ages.

Although total life expectancy for women initially living with someone or alone did not differ statistically at the selected ages shown in Table 3.6.2, this finding was sufficient to suggest that mortality risks for women observed to live alone at a given age were not higher than those for women living with someone, considering the dynamic transitions that may occur after the initial state. In addition, women of both initial states

were expected to spend roughly similar amounts and proportions of their subsequent life in institutions, suggesting no discrepancy in the expected duration of lifetime institutionalization between women initially living with someone and living alone.

Table 3.6.2. Women's Status-Based Life Expectancy in Three Living Arrangement States by Age

Age	Initial Status	Total (CI)	Not Living Alone (CI)	Living Alone (CI)	Institution (CI)	% in Living Alone	% in Institution
65	Not Alone	19.40 (19.06-19.74)	12.71 (12.37-13.05)	5.61 (5.31-5.92)	1.08 (1.01-1.15)	28.9	5.6
	Alone	19.48 (19.04-19.91)	4.65 (4.26-5.05)	13.66 (13.18-14.15)	1.16 (1.08-1.24)	70.2	5.9
	Institution	14.06 (12.15-15.97)	6.08 (4.17-7.98)	5.39 (4.29-6.49)	2.59 (2.10-3.08)	38.3	18.5
75	Not Alone	12.14 (11.92-12.37)	7.94 (7.76-8.12)	3.12 (2.97-3.27)	1.08 (1.01-1.15)	25.7	8.9
	Alone	12.44 (12.19-12.68)	2.15 (2.02-2.28)	9.03 (8.81-9.25)	1.25 (1.17-1.33)	72.6	10.1
	Institution	7.14 (6.48-7.80)	1.92 (1.53-2.32)	2.43 (2.01-2.85)	2.78 (2.52-3.04)	34.1	38.9
85	Not Alone	6.75 (6.55-6.96)	4.38 (4.22-4.54)	1.35 (1.24-1.46)	1.03 (0.94-1.12)	19.9	15.3
	Alone	7.16 (6.95-7.36)	0.76 (0.68-0.83)	5.07 (4.90-5.23)	1.33 (1.23-1.43)	70.8	18.6
	Institution	3.77 (3.56-3.98)	0.43 (0.35-0.51)	0.84 (0.73-0.95)	2.50 (2.37-2.64)	22.2	66.4

Note: Confidence intervals are shown in parentheses.

Discussion

Using the Markov-based multistate life table software, IMaCh, the current study estimates transition rates among different living arrangement states, implied prevalence of living arrangements, and population-based and status-based life expectancies for older persons by gender. The following discussion is generally organized around the four research questions stated at the start of the chapter. The discussion of these transition rates is not repeated in this section. Although the living arrangement categories are slightly different from other studies, the transition rates estimated in the study are generally consistent with those in a study using multiple decrement life tables by Wilmoth (1998) and another study using multistate life tables by Martikainen and colleagues (2014). In the following, we focus on the other three research questions that correspond to three major multistate life table functions calculated from the transition rates, and summarize these functions by drawing upon the transition rates findings.

Age-specific prevalence rates of living arrangements

Based on estimated transition rates among different living arrangement states, the current study presents age-specific prevalence rates for each living arrangement implied by these rates. Both genders had lower prevalence rates of co-residence at older ages, with a steeper age decline in these rates for men. Men have a higher prevalence rate of living alone at all older ages, while women's prevalence rate of living alone declines around age 85. The prevalence rate of institutionalization for men increases slowly with age, possibly due to the very high mortality rates in institutions for men. For women, their increasing prevalence of institutionalization at older ages coincides with a declining prevalence of living alone at similar ages. Evidence from transition rates suggest a

notable shift of living arrangements from living alone to institutions for women at the oldest old ages. Generally, men's prevalence rates of living arrangements are highest for co-residence, followed by living alone, and then institutionalization even at the oldest old ages. Women's prevalence rates of living arrangements have two crossovers. Roughly at age 80, prevalence rates for living alone exceed those for co-residence; by age 95, institutionalization became the most prevalent living arrangement among women who survived to that age.

Population-based life expectancies of living alone and in institutions

As population-based total life expectancy decreases for both genders with age, the estimated state-specific life expectancies suggest that men and women exhibit dramatically different age patterns with respect to their expected time spent living alone and in institutions. While at older ages, men are expected to spend an increasing percentage of their remaining life time living alone and in institutions, women's average time spent living alone remained roughly half of their expected remaining life. This is accompanied by a greater increase in the percentage of remaining life spent in an institution for men. The data suggest that living alone and in an institution are both essential living arrangements for women at older ages. In particular, these population-based life expectancies estimated from a sample of older Americans regarding the expected length of institutionalization as a percentage of total life expectancy at given ages are somewhat close to, though slightly smaller than, results from a multistate life table study based on monthly Finnish data (Martikainen et al., 2014).

Status-based life expectancies and selection process

Given the decreased total life expectancies for men and women at older ages, a critical question is whether these declines vary with respect to one's initial living arrangement observed at a given ages. Gender differences in status-based life expectancy are much more pronounced than in population-based life expectancy. The convergence of status-based life expectancies for co-residence and living alone at advanced ages may be related to the similar mortality rates for persons in these living arrangement states at older ages. Mortality rates did not differ for men living with someone or alone at age 85, but the rates are marginally higher for women living with someone than for women living alone, a pattern that is consistent with the differences in status-based life expectancies for men and women at age 85. For men, the difference between the status-based life expectancy of living with someone and living alone decreased with age. For men at age 85, status-based life expectancy of co-residence and living alone did not differ from each other. For women, the same life expectancies did not differ from each other as early as at the age of 65. At older ages, differences emerged suggesting that the expected length of remaining life among women living alone exceeded that of women living with someone, even though the difference is not statistically discernible.

In contrast to prior research that suggests the mortality risk associated with living alone, the current study demonstrates that living alone is not associated with shorter life expectancy relative to living with someone for women at all ages and for men at older old ages. Men initially living alone at older old ages tend to spend more of their subsequent life living alone and in institutions, while women initially living alone, on average, have relatively stable proportions of subsequent time spent living alone but expanded time

spent in institutions as they become older. For both genders, being observed in institutions at older old ages indicates that more of one's remaining time is expected to be in institutional care. This finding is consistent with that Martikainen and colleagues (2014).

While living alone is a simple state of a single-person household, in this study, living with someone includes living arrangements such as living with a spouse/partner, children, or other persons who are relatives or nonrelatives. Sample size limitations did not permit consideration of transitions among these alternative co-resident living arrangements. Interpretation of the substantive implications of the empirical findings should be exercised with caution.

Although we do not consider older persons' past history of living arrangements in the multistate life table because of the Markov assumption, the lack of differences in status-based life expectancy that solely depends on the current status may nevertheless suggest a selection process of living arrangements. Those who are able to live alone chose to live alone and do not suffer from shorter life expectancy. Some men and women observed living alone may not survive to a later age. Others may not be able to continue living alone, and transition out of it before reaching a given old age. For women at older ages, living alone suggests a longer life expectancy than living with someone, assuming the conditions at the given age remain the same, including income, support network, and so on. It is likely that those who are physically less robust or less resourceful may have transitioned out of living alone before reaching older ages. It would be a misinterpretation to conclude that living alone is beneficial at older ages because, very likely, with a potential selection process in place, individuals who survive to the given ages and live

alone are expected to live as long or longer on average than same-aged survivors in other living arrangements.

It is not possible, from the study results, to rule out higher risks of mortality or institutionalization being associated with living alone, because the differences, as shown in transition rates, are marginal, and "co-residence" is actually a complex grouping of different household compositions. However, it is justifiable to conclude that living alone may not be a risk factor of health and mortality compared to living with someone because of the dynamic nature of one's living arrangements. Treating living alone as solely a risk factor ignores the complex process of one's life course.

The study also shows that older women are expected to spend a longer time in institutions than men. With measurement limitations on shorter-term institutionalization, we are unable to fully examine the validity of life expectancy in the institutionalization setting. We are also unable to examine whether longer institutionalization among women than men is simply due to poorer health or other socioeconomic conditions that may be related to one's risk of entering an institution.

Limitations

Some limitations of this study should be acknowledged. First, the results do not consider the length of living arrangements or the history prior to the current living arrangement. Following the Markov model, the study assumed that the transition rate solely depends on the current state. Although some studies have reported dependence of prior history on subsequent disability transitions (Hardy, Allore, Guo, Dubin, & Gill, 2006), multistate life tables programs that permit estimation based on non-Markov or semi-Markov models are still limited (See Cai, Schneker, & Lubitz, 2006).

Second, due to the survey design and data construction, one is determined to be institutionalized if he or she was found to be living in an institution during the scheduled biennial interview or on the pseudo between-wave interview dates. It is not possible to determine how long this person has been institutionalized, because at biennial interviews, only the entry dates were reported; no exit dates were recorded. Although it is possible to measure the duration of institutionalization at the hypothetical between-wave interview dates, as many prior studies only focus on institutionalization that is longer than 90 days, the present study followed the survey design in the biennial HRS and did not specify the duration of between-wave institutionalization.

Third, the single state of co-residence with someone masks the process of transitions between living with a spouse and two other co-residence states. Thus, while marriage is commonly shown to be protective, this is not the case for co-residence with children or other persons. The combination of both living arrangements within "co-residence with someone" may cancel out any conflicting effects. In this sense, the results may not be substantially biased toward a particular direction.

Fourth, the current study does not attempt to provide estimates for the entire populations. The study follows a sample of community-dwelling older persons over time, even when they enter and exit an institution. This sample design is not representative of the entire population mainly because the baseline sample does not include institutionalized persons. Estimated results may be biased downward because institutionalized respondents at the baseline were excluded.

Fifth, as discussed earlier, IMaCh is capable of estimating Markov Chain parameters with a unit of time as short as a month. However, results for

institutionalization cannot be completely verified because monthly data for living arrangements—including institutionalization—are not available, at least for an extended period of observation time.

To overcome the issue of undercounted transitions among discrete states between observation intervals, we have employed IMaCh to estimate parameters that describe the embedded Markov Chain. Theoretically, month-to-month transitions should be described in a monthly transition matrix, producing corresponding life table functions. Wolf and Gill (2009) question the validity of the embedded Markov Chain approach. They point out that compared with estimates using true monthly data, individual parameters and age-specific transitions rates are biased when using annual and biennial interval data. However, these two sources of biases affecting transition rates offset each other, resulting in life expectancies that do not statistically differ from life expectancies using true monthly data.

It is likely that the monthly transition rates estimated in IMaCh assuming the embedded Markov Chain may not be as accurate as rates that are estimated using true monthly data. However, since living arrangement transitions are not common in an annual interval, transitions in a monthly interval are much rarer. One concern is mainly short-term institutionalizations beginning and ending within the same month. In other words, the study fully took advantage of IMaCh's strength in estimating monthly Markov chain parameters but was also potentially limited by its theoretical performance.

The current study found that older persons living alone may not necessarily have shorter life expectancy than those with a co-residence living arrangement. In particular, the life expectancy of women initially living alone at given ages is not statistically

different from that of women living with someone. Women's higher prevalence of living alone as well as the longer life expectancy when living alone than men may suggest a unique support network and biological strength among women who choose to live alone.

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CHAPTER 4

SUBSEQUENT TRANSITIONS IN LIVING ARRANGEMENTS AMONG OLDER AMERICANS WHO ARE LIVING ALONE

Introduction

Since the 1980s, there has been a trend of increasing numbers of older persons living independently in the community. Research suggests that a strong preference for independent living has been prevalent among older persons for many years (Shanas 1980; Troll, 1971), and that economic sufficiency helps support older persons' independent lifestyles (Michael, Fuchs, & Scott, 1980). In addition to the constant effect of income on living alone, structural changes at the societal level over time substantially increase the propensity to live alone (Pampel, 1983). At the time, there was a literature concerning who will take care of older persons, and how the long-term care system will be able to cope with the expected increase in need (Michael, Fuchs, & Scott, 1980; Mutchler, 1992; Soldo, Wolf, & Agree, 1990). Although research suggests that many older persons living alone appear to be financially and physically robust at any given point in time, these advantages do not necessarily translate into resources that can sustain or support a solitary living arrangement in the long run (Mutchler & Burr, 1991; Mutchler, 1992).

Older persons' living arrangements are dynamic processes that vary by age and the specific living arrangements under consideration (Börsch-Supan, 1990; Demey,

Berrington, Evandrou, & Falkingham, 2013; Evandrou, Falkingham, Rake, & Scott, 2001; Hays & George, 2002; Pendry, Barrett, & Victor, 1999; Wilmoth, 1998). Older persons may find themselves at a disjuncture in the life course, such as being widowed in a society that values the norm of the nuclear family household (Mutchler & Burr, 1991). But, at least for some people, this disjuncture may reflect a new norm or way of life in one's remaining years, because older persons living alone are unlikely change their living arrangement except to transition to an institution or death (Mutchler, 1992; Wilmoth, 1998). However, it is certainly not plausible to assume that older persons who are living alone face a constant risk of adverse health without considering alternatives, if any, for resolving their current living circumstances.

Few studies focus specifically on living arrangement transitions among older persons living alone (Multchler, 1992; Worobey & Angel, 1990; Spitze, Logan, & Robinson, 1992). Most recently, a study focusing on Mexican-origin Americans who were living alone found that increased financial strains did not push these ethnic minority persons out of living alone, but changes in functional health did (Prickett & Angel, 2015). Additionally, a very recent study provided strong evidence of the triggering forces of past hospital stays, falls, and increases in ADL and IADL disabilities on the odds of making a residential move (Friedman, Weden, Shih, Kovalchik, Singh, & Escarce, 2015). These studies suggest the need to reconsider the process of these life experiences in this important subgroup of older persons by integrating theoretical views with new methodologies and perspectives.

As we are facing an increasing number and proportion of older person who live alone, directing attention to older persons living alone provides more context and has

more practical meaning for addressing their potential needs. The rational choice model that incorporates economic resources, kin availability, and health serves as the theoretical base of the current study. Soldo, Wolf, and Agree (1990) described older persons' living arrangements as "outcomes of rational decision-making processes (p. S238). Mutchler and Burr (1991) viewed the choice of living arrangements as "a rational decision among competing living arrangements" (p. 566). Spitze, Logan, and Robinson (1992) referred to the pioneering research on living arrangement by Wolf and Soldo (1988) for a rational choice framework. Some studies have paid specific attention to the component of opportunity (kin availability) (Spitze, Logan, & Robinson, 1992; Soldo, Wolf, & Agree, 1990; Wolf & Soldo, 1988), while others focused on the component of resources and referred to "the resource model of living arrangements" (Burr & Mutchler, 2007). These studies used different terminology for the components of their respective frameworks for the same groups of variables. In fact, there is no consistency or consensus in the literature drawing on this broad undefined framework with almost identical variables. To be most inclusive, the current study focuses on the key concept of the rational process of making living arrangement decisions, discards the different components' names, and uses the rational choice model as the theoretical framework of the current study, comprising kin availability, economic resources, and health.

To understand the factors that underlie older persons' decisions to keep living alone or to make a transition to other living situations, this study begins with a review of the extant literature that explains the status and transitions of living arrangements for older persons. Of special interest are aspects of health changes, because kin availability, economic resources, and cultural preference are supposedly less volatile relative to health

changes. The extensive set of follow-up interviews of Health and Retirement Study respondents offers an opportunity to construct a picture of older men and women's life course while living alone. This study is able to analyze a representative sample of older men and women as observed living alone over a fourteen-year time span between 1998 and 2012. Multinomial discrete-time event history models are employed to investigate when and to what other living arrangement state older men and women transitioned after a period of living alone.

Literature Review

Rational Choice Model

Researchers have advanced our understanding of living arrangements of older persons by investigating the prevalence of living arrangement patterns at some point in time and changes in living arrangements between subsequent interviews. The rational choice model is often used as a theoretical foundation to explain the decision-making process of living arrangement decisions by older persons (Wolf & Soldo, 1988). Economic resources, kin availability, and health status are salient considerations for older persons when choosing their living arrangements (Mutchler & Burr, 1991; Mutchler, 1992; Soldo, Wolf, & Agree, 1990; Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Wolf, 1984; Wolf, 1994; Wolf & Soldo, 1988). As older persons face choices of living arrangements, they may weigh constraints against the resources available to them and their preference for their ideal living arrangements (Wolf & Soldo, 1988). Some living arrangements thus appear to be "more costly or more affordable" than others (Mutchler & Burr, 1991, p. 376). Evaluating such constraints and resources helps the older individual to better understand his or her chances of maintaining a solitary

living arrangement, sharing a household with others, or entering an institution. During the process, the individual should decide on the living arrangement that is most suitable given his or her circumstances. Theoretical perspectives and empirical results pertaining to the effects which economic resources, kin availability, and health have on living arrangement choices are further reviewed in greater detail.

Cultural Influences

In addition to a broad underlying preference for independent living, the differential patterns of living arrangements among different racial or ethnic groups have received great attention. Cultural influences associated with race and ethnicity appear to operate at a different level, whereby the influences of health, family, and financial resources are conditional on these cultural preferences (Burr & Mutchler, 1992; Hays & George, 2002; Worobey & Angel, 1990). The cultural preference is related to the common co-residential patterns among racial or ethnic subgroups. The norms of multigenerational households and supporting elders are well known. In fact, race and ethnicity by themselves have become an important focal point in studying the decision-making processes for older persons (Angel, Angel, McClellan, & Markides, 1996; Angel, Angel, & Markides, 2000; Burr & Mutchler, 1993; Burr & Mutchler, 1999; Choi, 1991; Coward, Peek, Henretta Duncan, Dougherty, & Gilbert, 1997; Gonzales, 2007; Prickett & Angel, 2015).

Economic Resources

Constraints in economic resources have also been a major focus in explaining how older persons decide whom to live with, or whether it is affordable to live independently. It is clear that those with insufficient economic resources are not be able

to decide their living arrangements solely based on their preferences (Mutchler & Burr, 1991). Income, in particular, accounts for most of the rising prevalence rate of living alone in the second half of the last century (Michael, Fuchs, & Scott, 1980; Pampel, 1983). For individuals with higher levels of income, living in a separate household was described as purchasing additional privacy (Beresford & Rivlin, 1966) or as a superior good (Burch & Matthews, 1987). Improved economic security allowed the unmarried elderly to exercise the option to live alone (Worobey & Angel, 1990). The notion of economic power was echoed by Costa (1999), who suggested that the decline in the prevalence of older unmarried women living with kin between 1950 and 1990 was largely attributable to Social Security benefits. Longitudinal studies also confirmed that income and income increases were positively associated with the chances that older persons will begin living as a single-person household (Mutchler & Burr, 1991; Mutchler, 1992; Schwarts, Danziger, & Smolensky, 1984). In addition to its association with living alone, some studies have also found a negative association between income and institutionalization risk (Burr & Mutchler, 2007; Worobey & Angel, 1990), while others have found no association (Mutchler & Burr, 1991; Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992).

A variety of measures of economic resources appear in the literature. Wealth is examined as an integral dimension of economic resources that generally exhibits more stable influences in the short term than income (Mutchler & Burr, 1991). While wealth has been less consistently found to affect living arrangements, part of the effects of wealth is likely a function of home ownership (Mutchler & Burr, 1991). Home ownership has been found to be associated with a lower chance of co-residence with others,

particularly children, in cross-sectional analyses (Soldo, Wolf, & Agree, 1990; Wolf & Soldo, 1988) but not in longitudinal analyses (Speare, Avery & Lawton, 1991; Spitze, Logan, & Robinson, 1992). Educational levels have been shown in some studies to be negatively associated with co-residence with children (Spitze & Logan, 1990; Ward, Logan, & Sptize, 1992), whereas limited effects of education on living arrangement transitions have been found in other studies (Burr & Mutchler, 2007; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990).

Kin availability

Kin availability was the one of the key considerations when the concept of living arrangement choice was first examined empirically (Wolf & Soldo, 1988). Drawing from experiences of dependent women, these early studies added to the literature concerning trends in fertility and personal income, and bridged the time series analyses that sought to understand the trend of independent living at the macro level and cross-sectional studies of household structure that provided more evidence at the micro level. Considering various aspects of offspring, this literature examined the decision-making process that leads older, unmarried women to live alone or co-reside with children. While studies examining the prevalence of different living arrangements found that the presence of one or more children reduced the chances of transitioning to or being observed living alone (Mutchler, 1992; Wolf & Soldo, 1988), other longitudinal studies did not find the number of children to be associated with the chance of living alone (Mutchler, 1992), or with greater dependence on others, or institutionalization (Worobey & Angel, 1990). Recently, a recent longitudinal study comparing living with a spouse or alone to living with others found that the odds of living with others were higher for those with more children (Burr

& Mutchler, 2007). Studies focusing on those who have been living alone show that once the one-person household is formed, the number of children ever born increases the likelihood of the older individuals sharing the household with children or joining a multi-person household, after controlling for income, health and demographic variables (Mutchler, 1992; Spitze, Logan, & Robinson, 1992).

Recent studies employing some measure of kin availability offered evidence of its relationship to transitions from community residence to institutionalization. These recent studies did not support the negative association between offspring and institutionalization risk. Worobey and Angel (1990) found that the number of children did not affect the likelihood of living with others or entering institutional care. Spitze, Logan, and Robinson (1992) found no significant associations between the number of children and institutionalization risk among older individuals living alone or with children. Similarly, having living sons or daughters did not affect one's risks for institutionalization (Speare, Avery, & Lawton, 1991).

In addition, past studies have argued that the characteristics of kin, and offspring in particular, are of significance in determining co-residence (Wolf & Soldo, 1988). Unmarried children were more likely to live with their unmarried mother, particularly unmarried sons (Wolf & Soldo, 1988). In a study of both living and care arrangements, the numbers of sons or daughters was not associated with their older mothers' living arrangements; however, the probability of living with a child was found to increase substantially by the number of daughters, when formal and informal services that the older mother received were considered (Soldo, Wolf, & Agree, 1990). Given that no substantial differences were found among individual characteristics, but previous family

constellations appeared to be critical in predicting living alone, Davis and colleagues (1996) concluded that individual characteristics may be less important than one's greater family network in explaining why older people live alone.

Health

Health and disability are generally considered constraints on choices of living arrangements in the rational choice framework (Wolf & Soldo, 1988; Soldo, Wolf, & Agree, 1990). Health can be seen as reflecting resources for independent living (Mutchler & Burr, 1991) or need for assistance (Spitze, Logan, & Robinson, 1992). For persons in poor health, their physical condition and the level of assistance they need lead to a lower likelihood of living alone and greater odds of living with others or being institutionalized. Measures of health are simply the activities of daily living (ADLs) or a compound indicator of both ADLs and instrumental activities of daily living (IADLs). This literature is mostly concerned with how a decline in health initiates living arrangement transitions, with a particular focus on institutionalization as a destination because of a common concern for informal and formal care that may not be available in the community for those in need of such care (Mutchler 1992; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990). This view of transitions as a help-seeking process associated with declining health is particularly relevant and matches perfectly with the developmental perspective of residential moves in late-life migration theory (Litwak & Longino, 1987; Hays, Pieper, & Purser, 2003). Similarly, the perspective of person-environment fit has been employed to explain how the environmental press caused by declining health initiates one's reconsideration of his or her living arrangements (Lawton, 1981; Wilmoth,

2000). Researchers have drawn on parallel theoretical views and discovered similar empirical findings.

Whereas rational choice, late-life migration, and person-environment fit perspectives consider poor health and declining health to lower the likelihood of living alone and increase the likelihood of co-residence and institutionalization, health has not always been found to be associated with changes in living arrangements. Some cross-sectional analyses have shown that those with disabilities are more likely to live with others than to live alone (Bishop, 1986; Soldo, Sharma, & Campbell, 1984; Tissue & McCoy, 1981; Wolf & Soldo, 1988). In contrast, some researchers have found that prior functional status was not associated with the decision-making processes in choosing of different community household living arrangements (Mutchler and Burr, 1991; Mutchler, 1992), but dominated the pathways to institutions (Mutchler & Burr, 1991).

When considering health decline that is concurrent with the change in living arrangements, studies have consistently reported the consequential effects of health decline (Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990). Worobey and Angel (1990) noted that the most striking finding in their study was that the strength of the preference for living alone among the unmarried elderly may outweigh the disadvantage of functional incapacity. Except for those with the greatest deteriorations in functional status, older men and women were able to cope with minor increase in disabilities and tended to continue to live alone two years later at the follow-up.

These results concerning concurrent changes in health were not without questions because due to data limitations, one cannot ascertain the time order of health changes and

living arrangement transitions (Speare, Avery, & Lawton, 1991; Mutchler, 1992), especially in studies that drew on data with only two observation points. Concerning this causal issue, recent studies provide new evidence by incorporating three-period observations at the cost of losing observations and generally support the triggering effect of health changes (Friedman et al., 2015; Stoeckel, 2011).

In short, independent living is considered a purchased privilege, a preference that one desires if possible, whereas co-residence is generally considered less desirable and is an indication of loss of independence or autonomy and dependence upon others. From the standpoint of family or kin network, living arrangements should be responsive to its members in need (Rogers, 1996). In contrast to the relatively consistent empirical findings concerning the effects of economic resources and kin availability, how health is associated with older persons' living arrangement is less clear.

In addition to co-residence, some studies have considered institutionalization as an alternative living arrangement (Mutchler & Burr, 1991; Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990). Fewer studies have considered death as one of the potential "destinations" of older persons' living arrangements (Mutchler & Burr, 1991). While some studies estimated transition-specific models that specify the origin and the destination of living arrangements (Mutchler, 1992; Spitze, Logan, & Robinson, 1992), most studies have solely focused on the destination that were conditional on a specified initial living arrangement (Mutchler & Burr, 1991; Speare, Avery, & Lawton, 1991; Wilmoth, 2000). As is discussed below, the latter approach is limited because the stability of living arrangements appears to outweigh the effect of health. Even though transition-specific models yield more sensible results

regarding the direction and destination of changes in living arrangements, transition-specific models require more data because each specific combination of origin and destination living arrangements is modeled separately. These additional combinations of transitions substantially exploit data for such transition-specific information and increase the difficulty of estimating stable models given a variety of transitions or outcomes.

Health and Living Arrangement Transitions

After the extensive research on older persons' choices of living arrangements around 1990s, more studies were devoted to examining the associations between health and living arrangement transitions using longitudinal data sets that became increasingly available for research. As studies tended to treat disability and living arrangements as social processes that do not operate independently from one another, some studies considered household living arrangements as critical environments for the development of disability (Waite & Hughes, 1999). Living arrangements as a household context were found to be either advantageous or adverse for the health of older household members (Hughes & Waite, 2002; Li, Zhang, & Liang, 2009; Rogers, 1996; Waite & Hughes, 1999).

Additionally, researchers who explored potential health effects on living arrangement transitions began to investigate other issues related to older persons' living arrangements. Deteriorating health and declining functional capability were found to initiate (1) changes in living arrangements (Brown, Liang, Krause, Akiyama, Sugisawa, & Fukaya, 2002; Liang, Brown, Krause, Ofstedal, & Bennett, 2005; Speare, Avery, & Lawton, 1991; Worobey & Angel, 1990); (2) relocation of residence (Longino, Jackson, Zimmerman, & Bradsher, 1991; Miller, Longino, Anderson, James, & Worley, 1999;

Speare, Avery, & Lawton, 1991); and (3) increases in proximity between generations (Michielin, Mulder, & Zorlu, 2008; Rogerson, Burr, & Lin., 1997; Silverstein, 1995; Zhang, Engelman, & Agree, 2013).

Several studies have aimed at investigating a full range of health measures and disentangling the effects of marital status on living arrangements of older Japanese (Brown et al., 2002), older Americans (Liang et al., 2005), and older Chinese (Zimmer, 2005). These studies have consistently found strong effects of prior living arrangement on the living arrangements observed at the present time. Although these studies specifically focused on differences in marital status, the current study focuses on their results related to health. While Liang and colleagues (2005) found no impacts of physical and mental health on current living arrangement once prior living arrangements were controlled for, Brown and colleagues (2002) found that the effects of older Japanese's sociodemographic characteristics on current living arrangements were mediated by their prior living arrangement, and that chronic conditions, poor functional status, and depressive symptoms retained direct impacts on the decision of one's current living arrangements when controlling for the prior living arrangements. Zimmer (2005) introduced interactions between health measures and gender, and found that health status was generally more important for older Chinese women than their male counterparts in determining living arrangements regardless of marital status. Although empirical results from different populations are difficult to compare, these studies consistently show that whether and the extent to which the effects of variables were mediated depended on marital status. These findings highlight the results from past research in asserting that one's living arrangement is a function of one's available resources and opportunity

structure, and that older persons' living arrangements are remarkably stable in the relatively short term.

Another stream of living arrangement studies has employed the same modeling strategy of event history analysis as operating in discrete time (Sarma, Hawley, & Basu, 2009; Wilmoth, 2000) or in continuous time (Hays, Pieper, & Purser, 2003; Pricket & Angel, 2015). Although the duration of current living arrangement may be not clearly specified in some studies, Sarma and colleagues (2009) found that the longer older Canadians lived, the more likely they were to transition to living in an institution and to intergenerational living arrangements.

In general, poor health status specified as time-varying was found to initiate living arrangement transitions in these event-history analyses. For example, higher levels of functional status reduced the likelihood of transitioning from independent households to either intergenerational living arrangements or institutional settings (Prickett & Angel, 2015; Sarma, Hawley, & Basu, 2009; Wilmoth, 2000). A cognitive deficit was associated with increased risks of first household expansion (increase in the number of household members) or institutionalization (Hays, Pieper, & Purser, 2003), and the same results were found among older Mexican-origin persons who were living alone for their transitions to co-residential living arrangements (Prickett & Angel, 2015). Depressive symptoms were unrelated to household expansion or institutionalization among those in various living arrangements (Hays, Pieper, & Purser, 2003), but were associated with co-residential living arrangement transitions among those living alone (Prickett & Angel, 2015). Moreover, hospitalization was not associated with the likelihood of adding more

household members or entering an institution among a study sample when current household composition was not considered (Hays, Pieper, & Purser, 2003).

Using the Duke Established Populations for Epidemiologic Studies of the Elder cohort (Duke EPESE), Hays and colleagues (2003) obtained measures of changes in ADLs, gross mobility, and cognitive problems from the estimated slopes of random-effects models for the respective health trajectories over time. A similar approach has been used for modeling the trajectory of self-rated health on mortality risks (Miller & Wolinsky, 2007). These estimated slopes for health changes were added to the event history models in addition to time-varying measures of the same health measures. The results showed that in contrast to the increased risk of those with cognitive problems, an increase in cognitive problems lowered the respective likelihoods of household expansion and institutionalization. Time-varying gross mobility difficulties, ADL deficits, and chronic illness burden were associated with lower risks of household expansion or institutionalization, but for each increase in mobility difficulties and ADL deficits, the risk of household expansion or institutionalization increased by 82% and 56%, respectively, over the course of a year. Hays and colleagues argued that there might be two groups in poor and better health observed at the same time in the process of living arrangement transitions.

In a study of Mexican-origin older persons who were living alone, Prickett and Angle (2015) simply measured whether the number of ADL difficulties increased and the cognitive status changed to a more disadvantaged state between the interview dates in addition to the already time-varying ADL and cognition measures. Their results were more straightforward, in that both the time-varying status and decline in disability and

cognitive status were associated with the risk of making a transition from living alone to a co-residential living arrangement.

Despite the increasing use of longitudinal data and event history models, these recent studies were based on study samples of community-dwelling residents without differentiating initial household types (Hays, Pieper, & Purser, 2003; Wilmoth, 2000), independently living persons living alone or with a spouse/partner (Sarma, Hawley, & Basu, 2009), and older persons who were simply living alone (Pricket & Angel, 2015). Various destinations of transitions have been specified, such as co-residential arrangement only (Pricket & Angel, 2015), intergenerational co-residence and institutionalization (Sarma, Hawley, & Basu, 2009; Wilmoth, 2000), or a combination of both household expansion and institutionalization (Hays, Pieper, & Purser, 2003). Only Wilmoth (2000) considered death as one of the destinations for older persons in various living arrangements. Although whether one transitions to co-residence or institutionalization may have been the primary interest of some studies, other studies have found differential transition-specific risks among initial living arrangements (Mutchler, 1992; Wilmoth, 1998; Wilmoth, 2000). While results from Sarma and colleagues (2009) were drawn on a sample of older Canadians due to their interest in studying publicly provided homecare, the findings of Prickett and Angel (2015) may actually underscore a unique cultural preference of living arrangement among Hispanics in general. Nevertheless, these inconsistent origin and destination combinations of living arrangement transitions create difficulties in comparing results from these studies. Although the longitudinal data provide a great opportunity to investigate various aspects

of living arrangements, it is necessary to integrate some of these approaches and perspectives in order to offer a general view of living arrangement transitions.

The current study focuses on living alone and transitions out of living alone as the primary interest. Following older adults who initially are living alone offers a starting point in an attempt to understand the trajectories of upcoming living arrangement transitions. In addition, older adults who are more likely to live alone often possess better health and more financial resources than persons who do not live alone. Thus, a major goal of this study is to draw on the rational choice models and to show how progression of health and disability during the period of living alone is related to subsequent living arrangement transitions.

Conceptual model

Although health and economic resources can lead to or sustain living alone, dynamic analyses of living arrangement transitions suggest that health conditions and functional limitations initiate changes in living arrangements (Speare, Avery, & Lawton, 1991; Spitze, Logan, & Robinson, 1992; Worobey & Angel, 1990), and that once they begin to live alone, older persons depart from their single-person households to co-reside with others only when kinship support is available (Mutchler, 1992; Spitze, Logan, & Robinson, 1992).

Theoretical models consider environmental changes to be protective and necessary for individuals at risk or in need of care (Litwak & Longino, 1987; Verbrugge & Jette, 1994). One important question is what are the living arrangement choices for the subsequent transition out of living alone? As they age, older adults tend to focus on relationships and individuals that are particularly valuable to them, and they purposely

reduce the size of their social network (Carstensen, Issacowitz, & Charles, 1999). When considering living arrangement options, the choice set is even more limited. One perspective takes the view that adult children are a primary source of care, subordinate only to spousal care (Litwak, 1985). Clearly, adult children among significant family members are crucial for providing older persons' living arrangement options. Past research often emphasized co-residence with adult children.

In contrast to other individual characteristics that are more stable or time-invariant related to living arrangement states and transitions (e.g., individual or cultural preferences), health conditions can develop and become progressively problematic over time. This illness process can only be captured through various measures of health and disability (Brown et al., 2002; Friedman et al., 2015). Due to this uncertainty, health and disability may be among the most significant factors conditioning living arrangement transitions that older adults cannot fully plan for in advance, a characteristic that may make it more relevant than other factors in understanding whether older adults continue to live alone or to make a transition.

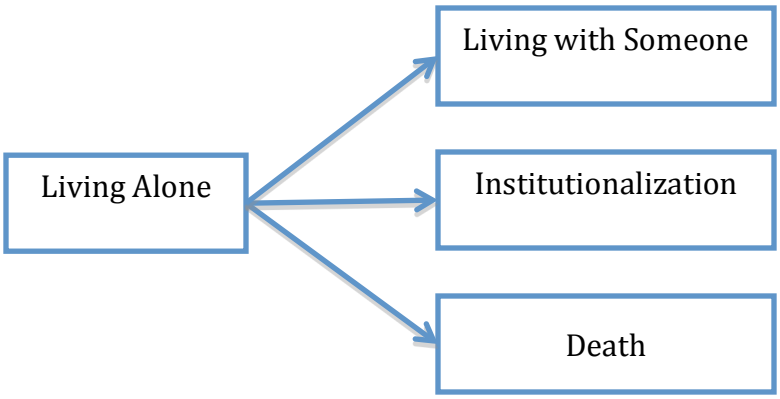
The current study expands prior research in three dimensions. First, influential factors emphasized differently by different studies are organized as a broad set of potential influences on living arrangement transitions. Economic resources, kin availability, health, and other variables that appeared in past research are all included without over-emphasizing a particular perspective.

Second, the study strikes a balance between sample size and sufficient transitions that make the estimation of empirical models feasible. The current study focuses on men and women living alone and their first living arrangement transition made at a subsequent

wave. This is crucial because destination-specific models without a clear origin living arrangement potentially mask or average the effects of variables on specific transitions. The study considers an exhaustive set of possible destinations of living arrangements for older persons, including death. This effort should mitigate concerns about biased estimates stemming from restricted study samples that past studies encountered. With specific attention paid to institutionalization and death, which received little attention in the past research, in this study co-residence with adult children and other persons is combined into a single co-residence category, avoiding estimation problems associated with small cell counts in transitions to certain living arrangements

Third, regarding the time span, the earliest studies of living arrangements entailed cross-sectional analyses, which were soon followed by longitudinal analyses that essentially compared living arrangement status observed at two interviews. With more follow-up surveys available for research, more recent studies have pooled three or four waves of survey data to augment sample size and the counts of transitions. Under the discrete-time event history framework, the current study exploits longitudinal survey data that track individuals up to 14 years at eight different time points to expand the time frame for a fuller observation of older persons' living arrangement transitions.

Figure 4.1. Subsequent Transitions from Living Alone



Living alone is defined as a state where an older adult lives in a single-person household. Once they enter this state, older persons are at risk of making a subsequent transition out of living alone. Older adults who live alone may continue doing so until they are censored due to the end of available survey data. Figure 4.1 shows that at a point of time, older adults in an initial arrangement of living alone face a choice among three living arrangements: co-residence, institutionalization, and death, relative to staying in their initial state. The subsequent transitions are competing events for older adults. One of the three types of events must eventually occur for older adults who live alone, and in this study, an older adult living alone can only experience either a first living arrangement transition out of living alone to co-residence in the community, a transition from community residence to institutionalization, a community exit to death without any transition, or no transition during the observation period.

Overall, older adults first observed as living alone are likely to maintain this solitary living arrangement without many subsequent transitions out of living alone (Mutchler, 1992; Wilmoth, 1998) before entering an institution or dying. The transitions

out of living alone may depend on the chronological age when an individual begins living alone, marital history, and duration of living alone. Nonetheless, the first transition after living alone is considered critical in this study since it is expected that older adults also tend to remain in the living arrangement to which they have transitioned. Although multiple and repeated transitions after living alone are possible, for parsimony this study focuses on the first transition out of living alone.

It is hypothesized that kin availability serves as the resources for subsequent co-residence, while higher economic resources lower the odds of subsequent transitions out of living alone. Transitioning out of living alone can be in response to increasing need for care associated with poor health and disability. Particularly, it is expected that a disability that develops catastrophically is more likely to initiate a transition out of living alone for older adults than for those who develop disability progressively over an extended period time. Older adults in the latter group may still maintain living alone status because they may be better able to make compensatory behavioral or environmental adjustments. In addition, this study does not preclude a situation where some transitions are made before actual disability onset if one's physical functioning has declined progressively. Individuals can also make a transition because they anticipate future needs for assistance rather than following an adverse event.

The research focuses on tangible changes, but acknowledges the above nuance about the decision-making process that may not be captured in the study. Note that some older adults who experience disability catastrophically may be at greater risk of institutionalization or death as the competing event with the first transition in the process of adverse selection. They may exit the community prematurely without having a chance

to make a transition; if a transition is made, catastrophic disability may continue to degrade their already poor health and increase the risk of exiting the community.

Conventionally, living with a child or with other persons who are relatives or nonrelatives are alternatives to living alone. Living with someone other than a child includes those who live with other relatives and non-relatives. It is assumed that individuals who choose to live with relatives or nonrelatives may encounter situations where support is not available from adult children or is supplemental to that provided by adult children. In addition, transitions associated with a remarriage will be temporally grouped into living with others with an assumption that benefits associated with marriage may be an incentive for those who choose to remarry (Lillard & Panis, 1996). For parsimony, living with children, living with other persons, and living with a new spouse or partner are all aggregated together as living with others, a single co-residence alternative to living alone. Regarding institutionalization, due the design of the HRS interview, it is only possible to know that the respondent was living in an institution at the time of interview. Information about when a respondent left the institution is not collected. Potentially, the institutionalizations observed at each interview of the HRS include both long-term institutionalizations and shorter-term post-acute-care institutionalization.

Methodology

Data

This study used eight waves (1998-2012) of the Health and Retirement Study (HRS) and followed subsequent living arrangement transitions among older persons who were aged 65 and over and lived alone at first observation between 1998 and 2010. Older

adults may enter the state of living alone at different ages and from different types of living arrangements and marital statuses. The study identifies older adults who were living alone at some time between 1998 and 2010, and models their transitions of living arrangements afterward. Prospective information over the 14-year observation period on household living arrangements, institutionalization, and mortality status was constructed from raw HRS files (updated to March 2015) and the HRS Tracker File Final 2012 (V1.0, March 2015). Other measures were constructed from the RAND HRS Data files (Version N, September 2014) that have been cleaned and streamlined to facilitate research usage.

The original HRS cohort was implemented among community-dwelling individuals who were aged 51 to 61 in 1992 and followed up approximately every two years since then. The Aging and Health Dynamics (AHEAD) survey that focuses on persons aged 70 and older was initiated in 1993 and reinterviewed in 1995. In 1998, the original HRS and AHEAD were combined as a single panel study and joined by two additional cohorts—the Children from the Depression (CODA) and War Baby (WB), consisting of a nationally representative sample of individuals aged 50 and older. Since the age threshold for the study sample is set at 65 and over, the age-eligible baseline respondents mostly belong to the AHEAD (aged 75 and over in 1998) and CODA (aged 68-74 in 1998), and part of those belong to the original HRS (age 57-67 in 1998).

Retrospective information on living arrangement prior to 1998 was constructed for respondents of the AHEAD and HRS cohorts, but not for those of the CODA cohort, since they were first interviewed in 1998. Tracking living arrangements status prior to 1998 among these baseline respondents is necessary to account for potential effects of

living arrangement history for those older respondents who have been living alone prior to 1998 for an extended period of time (no earlier than 1992 based on the HRS history).

The extended observation window in the HRS is an important property for longitudinal analysis. First, the HRS allows a wide time frame to capture living arrangement transitions and ensures a reasonably sufficient number of observations for statistical analyses. Second, the HRS's rich household structure information facilitates the construction of respondents' living arrangement histories. Multiple and repeated transitions are expected for some sample members and will be recorded accordingly, although much of the study focuses on the first transition out of living alone.

Defining risk set

The study considers older adults living alone at risk of making the first subsequent transition out of living alone when they are older than 65 during the observation period. In other words, the risk period begins only when those who are living alone are aged 65 and older. This definition corresponds to the dynamic process of living arrangement transitions, since it is observed that transitioning into living alone occurs at any age, albeit at varying rates. Due to different marital statuses or decisions made in early life, some older persons may begin living alone much earlier than the time when they reach older ages. However, past research suggests that relatively few of these middle age adults younger than 65 years who live alone transition out of living alone prior to age 65 (Wilmoth, 1998). The extended time period of living alone prior to age 65 is not considered a period where individuals are at risk of subsequent transitions. Old age respondents are considered at risk of transitioning out of living alone if they are living alone because the resources for maintaining solitary living arrangements in later life are

different for persons younger than 65. In addition, prior research has considered age 65 as a plausible age when there is some risk of nursing home entry (Freedman, 1996; Kasper, Pezzin, & Rice, 2010). Practically, it is also simply not possible to track respondents' earlier living arrangements in middle age, since not all HRS respondents entered the study at ages younger than 65.

Under the definition of the risk period, three groups of older persons were observed living alone between 1998 and 2010. First, a large number of respondents were aged 65 or older in 1998 and had already been living alone prior to 1998. Second, some respondents were living alone at the baseline in 1998 but only reached age 65 at a point in time between 1998 and 2010. Third, others began living alone sometime between 1998 and 2012 and were aged 65 or older either at the time of the transition or afterward. The first group is composed of "late entrants" whose times living alone were tracked backward from 1998 to 1992, the earliest wave of the HRS. Their survival time has to be handled in a way that reflects their exposure to the risk of transitioning out of living alone before the start of the observation period in 1998. This issue is discussed later in detail. For the second group, the study only considers their survival time since age 65, and discards person-period intervals prior to age 65. For the third group, their survival time starts at the time an individual turned age 65 after first observed living alone after 1998, or at the age an individual already older than 65 began to live alone. Note that this research design only focuses on the respondents who were observed to be living alone between 1998 and 2010. The design omits those who lived alone in earlier waves but departed from living alone prior to 1998. If a respondent had multiple episodes of living

alone during the twelve-year observation period, only the first observed episode is considered.

Study sample

The baseline sample was first restricted to community-dwelling respondents in 1998 who were aged 65 and older between 1998 and 2012 (n=18,050). Specifically, those who were institutionalized in 1998 and those who did not reach age 65 during the observation period were omitted. Respondents belonging to any racial or ethnic groups other than non-Hispanic white, non-Hispanic black, and Hispanic were also excluded because their small numbers preclude meaningful results. I also removed 458 respondents (2.5%) from analyses due to their missing data at baseline: 1.6% were missing in one variable, and fewer than 1% of baseline respondents had missing data for up to three variables. The missingness does not appear to be systematic because it is not concentrated on any particular variable. In addition to excluding respondents with missing data for key variables at baseline, another 144 respondents were excluded because of ambiguous marital status at the start of their episode of living alone. Their marital status was unable to be clarified by the end of observation because no information on marital dissolution in the form of divorce, separation, or spousal death was found.[1] Most of these respondents with ambiguous marital status reported being married with their spouse absent in the household. Others reported being partnered and living alone. They were excluded

[1] In a separate analysis, most married respondents with spouse absent were found in subsequent waves to either be married and living with their spouse or having their marriages dissolved due to divorce, separation, or spousal death. Twenty-one respondents reporting spousal absence had their spouse back in subsequent waves. One hundred and six respondents reporting spousal absence subsequently neither had their spouse back in the household nor had their marriage dissolved. Only 17 respondents reported being partnered at the time of living alone.

because I was not able to determine whether their subsequent marital statuses were the result of marriage or partnership to the same spouse or partner. Overall, 602 respondents (3.3%) were removed from subsequent analyses, leaving 17,448 baseline respondents in the analysis.

These baseline respondents were followed through 2010 to determine their first observed living alone status. Those who were observed to live alone in 2012 were not included in the analysis because there is no information available regarding their subsequent status of living arrangements. The majority of the baseline respondents (n=11,204) were not observed in a single-person household during the observation period. However, 6,244 respondents were first observed living alone at some point in between 1998 and 2010, including those living alone prior to baseline and those newly living alone since baseline. These age-eligible respondents were followed for their first living arrangement transition out of living alone until 2012. Their experiences of living alone are fully observed during the observation window or until they died

Among these respondents who at some point lived alone, 196 (3.1%) were excluded from discrete-time event history analysis because of missing data in time-varying variables. The exclusion is unlikely to bias the sample because the percentage is low, and variables with missing data were less than 1%, except for body mass index (2.9%). The discrete-time analysis was based on this living alone sample with complete data (n = 6,048).

Analytic Plan

The study begins with the descriptive analysis of the baseline respondents. To gain more insight into how older adults transition from living alone, the study explores

how older adults' status at baseline was related to whether the individual was living alone or not during the observation period. Throughout the observation period, age-eligible respondents may be found not living alone but instead co-residing with someone at all observations until deceased or censoring. For illustrating potential heterogeneity between the two groups, individuals living alone subsequently between 1998 and 2010 were further differentiated into two subgroups: those who transitioned to living alone in 1998 or later and those who were observed living alone prior to 1998.

Next, discrete-time event history models were estimated through multinomial logistic regressions on the occurrence of subsequent living arrangement transitions among older persons who were first observed living alone. Older adults living alone can transition from it via co-residence, institutionalization, and death. Nonresponse at the first wave following living alone was treated as right-censored because these respondents were alive, and re-interviews were attempted in subsequent waves. The risk of these non-respondents experiencing a transition to co-residence, institutionalization, or death is unlikely to dramatically differ from respondents who were right-censored. In total, the 6,048 respondents from the living alone sample contributed 17,358 person-intervals.

Although individual respondents' living alone histories are the focus of the analysis, each interval of a living arrangement state that an individual occupies is the unit of analysis in the discrete-time hazards models. In a general sense, time in the current study refers to the interview waves in which respondents were interviewed and observed. Survival time for an episode of living alone was recorded between the initiation and termination of the particular living arrangement state as determined from biennial HRS interview dates. Thus, survival times of each living alone episode are interval censored

and can be seen as grouped into discrete-time intervals between successive interviews. Since the respondents were interviewed approximately every two years, I consider the discrete intervals of time as being of equal length. Thus, discrete-time survival models estimated using the maximum likelihood method are suitable for analyzing the discrete survival time of living alone.

The first set of discrete-time hazard models only assesses the effects of the duration of time spent living alone, age and marital status at the start of living alone, race and ethnicity, economic resources, and kin availability on the relative risks of transitioning subsequently from living alone to various destination living arrangements: co-residence, institutionalization, or death. The next two sets of models consider sentinel health events and functional status on subsequent living arrangement transitions. The fourth set of models further includes additional control variables. Lastly, based on a subsample of survivors, the potential influences of concurrent changes in functional status are examined. All the models were estimated separately by gender.

Stata 12.1 was used for estimation (StataCorp, 2011a). All the models were adjusted for complex sampling design of the HRS by applying baseline sampling weights with Stata's svy routine. Note that model fit statistics for multinomial logit models are not reported from Stata when svy is applied (Brown, Bulanda, & Lee, 2012; Zhang & Hayward, 2006). For reference, pseudo R-squares were reported with normalized personal weights applied, instead of Stata's svy. Same coefficients were obtained with or without applying Stata's svy.

Left Truncation

The study considers older persons living alone at risk of a subsequent transition to other living arrangements or death when they reach age 65. The focus on time until subsequent transitions introduces the issue of left truncation bias: some respondents come under observation after having been exposed to the risk of event occurrence for a while (Guo, 1993). Left truncation is an issue that only a few studies of living arrangement transitions have considered (See Freedman, 1996; Van Hook & Glick, 2007 for exceptions). In the current study, a large number of older persons aged 65 and older in 1998 had been living alone prior to 1998. The experience of living alone of these respondents is left truncated. They are also referred to as late entrants to the risk set because they had been at risk of subsequent transitions prior to baseline and were observed in the risk set relatively late during their course of living alone (Singer & Willett, 2003). Left truncation is often seen in stock samples, because age-heterogeneous respondents may have already occupied the initial state for some time when data collection began (Singer & Willett, 2003; Rabe-Hesketh & Skrondal, 2008). Failing to account for actual start times of living alone prior to baseline can lead to bias in the estimated hazard function (Freedman, 1996; Singer & Willett, 2003).

One data manipulation strategy for dealing with left-truncated histories in discrete-time data focuses on specifying the entry time to the risk set (Jenkins, 1995; StataCorp, 2011b). Essentially, it entails tracking the start times of the initial state so that the entry time to the risk set can be properly specified. If a respondent enters the risk set at or after baseline, his or her entry time is 0, and time until a subsequent transition is clocked from time zero. If the other respondent enters the risk set late with the

observation prior to baseline being left truncated, his or her entry time should reflect the time since the current state began, rather than the start of the observation period (e.g. the observed risk period starts at time 4 of living alone, instead of time 0), and time until a subsequent transition is clocked accordingly. Note that the person-intervals in the discrete-time data prior to the beginning of the risk set are discarded, but the entry time to the risk set is retained and used as the main time effect in the discrete-time event history model. In the likelihood specification, this is equivalent to subjecting the likelihood of observing transitions out of living alone to the condition that one has survived to the point being observed living alone at baseline and subsequent time intervals (Jenkins, 1995; Rabe-Hesketh & Skrondal, 2008). In the current study, the entry time is specified as time since both being old and living alone, while age at the start of living alone is specified as one of variables.

Available information was gathered from early HRS waves before 1998 to quantify the duration of living alone prior to 1998 for late entrants. A practical problem emerges. It is possible to track living arrangement status prior to 1998 for many older persons who were 65 and older and living alone at the time, but it is not possible to do so for every late entrants. Some of these respondents may have been age 65 and older and living alone prior their first HRS interview, such as respondents whose HRS entry cohorts are AHEAD (age 70 and older in 1993) or CODA (age 67 and older in 1998). Some of them were late entrants for sure, while others may have begun living alone after age 65 as they were observed in the survey. Because there are no data on living arrangements available prior to their entry to the survey, their entry time to the risk set for

such individuals was clocked since their first entry to the HRS; their age at the start of living alone is measured as the age when first observed living alone in HRS data.

In practice, among the 6,048 respondents for the discrete-time analysis, 1,554 of them (25.7%) are determined to be late entrants as they were living alone in 1998 and observed living alone prior to 1998. These late entrants belong to either the HRS cohort (first entry in 1992; n=257) or the AHEAD cohort (first entry in 1993; n=1,297). The HRS late entrants turned age 65 while living alone in 1994 or 1996 with their status of living alone that is traceable. The status of living alone for the AHEAD late entrants can only be traced back to 1993. However, in the discrete-time study sample, 554 respondents of the CODA cohort first entered the HRS panel in 1998 and were observed living alone at the time. Their entry time to the risk set was set at 1998 because the information on when they began living alone is not available. Thus, all of these 554 respondents were not treated as late entrants.

In addition, person-period intervals for early AHEAD respondents may not be two year in length, as they were interviewed in years different from the original HRS respondents prior to 1998. The current study has to compromise on the information of the entry time to the risk set prior to 1998 for the left-entrants who belong to the AHEAD or CODA cohorts. With the information that is not exactly precise regarding the beginning of living alone, the current study is still able to approximate the effect of considering late-entrants. A dichotomous variable indicating that the observation of a respondent is left truncated was included in the discrete-time hazard models for examining the extent to which the incomplete and imprecise entry times bias the estimated baseline hazards.

Measures

Living arrangements. The study defines older persons' living arrangements in four mutually exclusive categories: not living alone, living alone, institutionalization, and death. The four categories of living arrangements are constructed hierarchically by checking respondents' mortality status, institutional residency, and household member presence at the time of biennial interview dates accordingly. Living alone is defined as living in a single-person household at the time of the interview. Not living alone was aggregated to include living with a spouse or partner, children, or other persons due to sample size. For mortality status, priority is given to the National Death Index (NDI) matched in 2008 over the proxy mortality reports. A proxy report of mortality information was used instead if no NDI records were found. Living alone, institutionalization, and death are defined the same as the schemes used in Chapters Two and Three.

Age and marital status at the start of living alone. As older persons begin living alone at different ages and with various marital statuses, it is essential to model these differences with respect to older persons' baseline living arrangements and their subsequent pathways of living arrangement throughout the observation period. The two variables describe the status of respondents at time they are first observed living alone. Age at living alone is the age when the respondent was first observed living alone, which may be prior to or after the baseline in 1998. Marital status when first observed living alone was specified using three categories, including separated or divorced, widowed, and never married.

Cultural preference. Past research suggests that race and ethnicity may serve as indicators of cultural preferences for family living arrangements (Burr & Mutchler, 1992; 1993). Respondents are identified as non-Hispanic Whites, non-Hispanic Blacks, and Hispanics.

Kin availability. Past literature on kin availability tends to focus on the overall number of living children. The current study extended the measurement of kin availability by separately specifying the numbers of sons and daughters and including the number of unmarried children. Previous research suggests that the gender of caregivers generally coincides with the gender of care recipients (Soldo, Wolf and Agree, 1990), and sons and daughters play different roles and are involved in different tasks in older parents' care (Spitze & Logan, 1990). Children' marital status may indicate the life course status of the children, but also the potential capability for (or expectation of) caring or their parents. Unmarried children, sons in particular, were found to more likely to live with their unmarried mothers (Wolf & Soldo, 1988). Numbers of these kin were specified so that those respondents without a living child or sibling can be retained in the analysis.

Economic resources. Three measures are specified for economic resources: personal income, non-housing wealth, and homeownership. Michael, Fuchs, and Scott (1980), Wolf (1984), and Wolf (1990) found that income is positively associated with the chance of living alone. Further, Davis and colleagues (1996) found that education and income impose effects of different directions on the likelihood of living alone Both personal income and non-housing wealth were logged because of the skewed distributions.. A constant was added to each measure before taking the log when the original measure containing negative values.

Sentinel events and functional Status. Sentinel events include the number of life-threatening or fatal conditions (hypertension, diabetes, stroke, non-skin cancer, chronic lung disease, and heart disease), the number of hospital stays in the past two years, and history of falls in the past two years. The number of life-threatening conditions indicates the sum of these six conditions that have been diagnosed. The six conditions are considered serious and life-threatening, and thus differ in effect for subsequent transitions (Friedman et al., 2015). They are differentiated from chronic conditions, such as arthritis (Brown et al., 2002; Ferraro & Farmer, 1996; Liang et al., 2005; Pienta, Hayward, & Jenkins, 2000; Zhang & Hayward, 2006). Past hospitalizations were specified as none, having had one hospital stay, and having had two or more hospital stays in the past two years. Fall history indicates no falls, having had one fall, having had two or more falls, or having had any injurious falls in the past two years. Functional status includes activities of daily living (ADL) and instrumental activities of daily living (IADL). While ADL tasks assess the ability of self-care, IADL tasks assess the ability of household management. ADLs include whether respondents had difficulties in five tasks: bathing, eating, dressing, walking across the room, and getting in or out of bed. The IADLs tasks include using a telephone, taking medicine, managing money, shopping, and preparing meals. The functional status measures were directly taken from the RAND HRS data set, which impose specific assumptions for the consistency of measures across waves. A "can't do" response is considered having some difficulty, whereas a "don't do" response is treated as missing.

Control variables include cognitive and emotional health, health behaviors, and social support. Cognitive impairment and emotional problems were controlled in the

analyses because the study focuses on changes in physical health. Whether a respondent is cognitively impaired is defined based on whether he or she is a self or proxy respondent. The HRS assesses cognitive functions of self-respondents on six cognitive tasks, including immediate recall, delayed recall, naming the day of week and the date, naming objects, a serial 7's test, and backward counting. The total scores of six cognitive tasks yield a 35-point scale. Herzog and Wallace (1997) suggested a cutoff of 8 (out of 35) for severe cognitive impairment. Langa and colleagues (2008) followed the same suggestion and considered a cutoff of 10 (out of 35) for normal cognitive functioning. For the proxy respondents whose cognitive measures were skipped and not available in the HRS, their cognitive impairment was defined as reporting to have poor or fair memory (Langa et al., 2008; Kasper, Pezzin, & Rice, 2010). As studies have reported psychological distress among older persons who live alone (Stone, Evandrou, & Falkingham, 2013), whether the respondent has emotional or psychiatric problems was specified. Depressive symptoms are also suitable to indicate psychological distress. These were not used in the analyses because proxy respondents were not asked to evaluate their depressive symptoms.

For health behaviors, the study identified respondents who were heavy drinkers and current smokers along with their body mass index (BMI) measured by weight relative to height. Heavy drinkers are defined as having three or more drinks per day when they are drinking. Current smokers are defined as smoking cigarettes currently, regardless of one's past smoking history. BMI is calculated as weight divided by the square of height. The study also included having any children living within proximity,

having relatives living in the neighborhood, and having friends in the neighborhood as indicators of social support.

Results

Descriptive Analysis

Table 4.1 shows demographics, kin availability, economic resources, health status, health behaviors, parent-children proximity, and falls and hospitalization that were observed at baseline by gender for respondents who were never observed living alone and those living alone during the observation period. Differences were tested using pairwise t-tests.

At baseline, older men who were living alone prior to or since baseline were significantly older, are less likely to be white but more likely to be black, have smaller kin networks, less economic resources, and poor physical health status, as measured by ADLs and IADLs, and emotional health than men never living alone. These men who have at some point lived alone are also less likely to be a homeowner and more likely to be a smoker and of normal-weight than men who have never lived alone. Note that men who have never lived alone are more likely to be obese or overweight and have children living within proximity than men living alone. In particular, men have ever lived alone in or after 1998 are more likely to have relatives or friends living in their neighborhood, and more likely to have life-threatening conditions and experience multiple and injurious falls than men who have never lived alone.

Table 4.1 also shows female respondents' baseline characteristics by whether they have ever live alone at some point since baseline. Similar to their male counterparts, women who have lived alone are significantly older, and have smaller kin networks and

lower non-housing assets than women who have never lived alone. In contrast, women who have lived alone are less educated and are more likely to be white but less likely to be Hispanics, while reporting modestly, yet significantly, higher personal income and less IADL disabilities or cognitive impairment than women who have never lived alone. Also similar to men, women who have lived alone are more likely to be normal weight, living close to relatives or friends, having more life-threatening conditions and multiple or injurious fall experiences than women have never lived alone. No difference in parent-children proximity is detected. Women who have alone are more likely to have one hospitalization, while women in the same situation do not appear to be at greater risk of having multiple hospitalizations.

Table 4.2 describes age and marital status at the start of living alone for all respondents who have ever lived alone and respondents who lived alone at an early point prior to baseline. While Table 4.1 describe respondents have ever lived alone as a group, it is important to note that these respondents may begin living alone prior to baseline or transition to the solitary living arrangement years after baseline. The mean age at the start of living alone is roughly 72 years for both men and women who ever lived alone. Spousal death appears to be the major cause for men and women to begin living alone. As for the marital status of those who have ever lived alone, 56% of men and 75% of women were widowed at the start of living alone, followed by 34% of men and 20% of women who were separated or divorced at the start of living alone.

Considering age at the first observation of living alone, both men and women who began living alone prior to baseline are significantly older than those who have lived alone at some point since baseline. However, it should be remembered that information

about age at the start of living alone indicates the age of respondents already living alone at their first observation of the HRS panel. Despite this data deficit, a substantial gap in mean ages at the start of living alone is still observed between those who have different starting years of living alone, prior to or after baseline.

Regarding marital status at the start of living alone, the late entrants who began living alone prior to 1998 were significantly less likely to be separated or divorced but more likely to be widowed. About 72% of male late entrants and 85% of female late entrants were widowed when they were first observed living alone. The percentage of men who were never married when they began living alone is higher than that of women. For women, no differences in the percentage of never married were detected among the groups with different starting years of living alone.

Table 4.1. Sample Characteristics for Age-eligible Respondents by Ever Having Lived Alone or Not, 1998 (Weighted Means or Percentages; *N* = 17,090)

	Men (n=7,418)		Women (n=9,672)	
	Never Lived Alone	Has Lived Alone[a]	Never Lived Alone	Has Lived Alone[a]
Age	64.3	69.5***	63.4	71.0***
Race/ethnicity (%)				
White	86.8	83.6**	82.8	85.7**
Black	7.0	11.5***	9.6	9.5
Hispanic	6.2	4.9†	7.7	4.8***
Years of education	12.6	11.8***	12.2	11.9***
Personal income (Ln)	10.3	10.0***	9.4	9.5***
Net worth-nonresidential (Ln)	10.6	9.8***	9.9	9.2***
Homeowner (%)	84.1	63.9***	79.9	66.8***
Number of sons	1.7	1.3***	1.6	1.4***
Number of daughters	1.6	1.3***	1.6	1.4***
Number of unmarried children	1.4	1.0***	1.4	0.9***
Life-threatening conditions (0-6)	1.0	1.1***	0.8	1.0***
Hospitalization (%)				
No hospitalizations	74.3	71.7	77.8	73.5***
One	15.7	16.8	14.2	17.6**
Two or more	10.0	11.5	8.0	8.9
Fall history (%)				
No falls	87.9	82.6***	87.1	76.8***
One without injury	3.5	5.9**	3.4	6.9***
Two or more without injury	5.4	7.0*	4.3	6.9***
Injured falls	3.2	4.5*	5.2	9.4***
ADLs (0-5)	0.21	0.29**	0.34	0.34
IADLs (0-5)	0.19	0.23†	0.30	0.26*
Cognitive impairment (%)	4.5	4.2	4.1	2.9**
Emotional problems (%)	5.8	8.5**	11.6	11.4
Heavy drinker (%)	12.3	12.4	2.9	2.2*
Current smoker (%)	16.1	20.8***	15.4	15.2
Body mass index (%)				
Obese	23.1	17.8***	24.2	20.5**
Over-weight	47.7	44.9†	33.2	32.9
Normal weight	28.5	36.3***	39.8	43.1**
Under weight	0.7	1.1	2.9	3.5
Proximate children (%)	51.7	48.4*	53.6	54.6
Near relatives (%)	28.2	31.5*	28.2	31.9***
Near friends (%)	66.6	70.1*	65.3	73.1***
Unweighted *n* (Weighted %)	5,771 (77.8)	1,647 (22.2)	5,350 (55.2)	4,322 (44.8)

Note: All values are weighted for adjusting complex sampling design.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.
[a] Compared with having never lived alone.

Table 4.2. Age and Marital Status at the Start of Living Alone among Men and Women Having Ever Lived Alone

	Men		Women	
	Has Lived alone[a]	Has Lived alone prior to 1998[b]	Has Lived alone[a]	Has Lived alone prior to 1998[b]
Age at living alone	71.6	76.6***	72.2	76.7***
Marital status at living alone				
Separated or divorced	33.6	20.5***	20.1	10.4***
Widowed	56.2	72.2***	74.9	85.3***
Never married	10.2	7.3*	5.1	4.3
	1,647 (100.0)	320 (18.2)	4,322 (100.0)	1,226 (28.1)

Note: All values are weighted for adjusting complex sampling design.
†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.
[a] Include those living alone prior to 1998 and those living alone in or after 1998.
[b] Compared with having lived alone in or after 1998.

Discrete-time Survival Model

Sentinel Health Events, Functional Status, and Relative Risks Of Subsequent Transitions

Tables 4.3 and 4.4 contain estimates of discrete-time survival models for men and women, separately. Empirical results are reported in the form of relative risk ratios (RRRs) for living arrangement transitions in the subsequent wave relative to continued living. To fully examine the influences of sentinel health events and functional status on the likelihood of transitioning out of living alone, four model specifications are shown. Model 1 contains variables for the time effect, the late entrant indicator, status at the start of living alone, race or ethnicity, economic resources, and kin availability. This basic model illustrates major influences on the relative risks of transitions in the past research that can be used for comparison with effects of sentinel events and functional status as added in sequence in Models 2 and 3. Three types of sentinel health events (counts of life-threatening conditions, inpatient hospitalization, and fall history) are specified as

additional covariates in Model 2. Counts of ADLs and IADLs are added as time-varying indicators of poor health that may mediate the effects of sentinel health events. Lastly, additional control variables are added to the model specification, including cognitive and emotional health, poor health behaviors, and social support.

Men's transitions from living alone

The models in Table 4.3 show that as the duration of living alone increased, the risk for older men to transition to living with someone relative to continued living alone decreased, while the risks of institutionalization and death increased with time. For each period of living alone among older men, the relative risk of transitioning to co-residence with someone versus continued living alone were about 13% lower, but the relative risk of entering an institution or dying were about 10% higher, respectively. Note that the probabilities of subsequent transitions did not appear to vary by whether older men were living alone prior to baseline or began living alone in or after baseline. The hazards of late entrants transitioning out of living alone did not statistically differ from those men who began living alone during the observation period.

The results in Table 4.3 also show very different influences of age and marital status at the start of living alone on the relative risks of older men transitioning to different destinations. Age at the start of living alone was not related to risk of a subsequent transition to co-residence, but it was related to higher risks of subsequent institutionalization and death. For each additional year older that men were at the start of living alone, the relative risks of a transition to institutionalization and death within 2 years increased by 8% and 6%, respectively. Older men's marital status at the start of living alone did not necessarily indicate a remote influence on the likelihood of

subsequent transitions. In contrast to the expectation, the relative risk of subsequent co-residence for men who were separated or divorced at the start of living alone did not differ from that of widowed men. In other analyses that only specified the marital status and age at the start of living alone (not shown), never-married men who were living alone were half as likely to subsequently co-reside with someone as widowed men, and being separated or divorced was associated with a 26% higher relative risk of mortality than being widowed. Additional analyses (not shown) suggest that these marital status differentials for co-residence were mostly explained by kin availability, and economic resources accounted for most of the differential mortality risks between men who were separated or divorced from men who were widowed.

The results in Table 4.3 also suggest one surprisingly large racial/ethnic difference in the relative risks of transitioning out of living alone. Hispanic men who were living alone were more than twice as likely as non-Hispanic white men to co-reside in the subsequent wave. Otherwise, no racial or ethnic differences in subsequent transition risks were found. Among the economic resources variables, education was the only one that was not associated with the risks of subsequent transitions out of living alone. Higher personal income was associated with a marginally significant relative risk of subsequent co-residence and lower relative risks of institutionalization and death. Non-housing net assets were not associated with subsequent co-residence but older men with more non-housing net assets had a reduced the relative risk of subsequent institutionalization. Similar results were found for homeownership, except that greater homeownership was associated with even greater reductions in the likelihood of subsequent institutionalization and death than increases in non-housing assets. Older

male homeowners who were living alone were roughly 30% less likely to enter an institution or die, although the relative risk for subsequent institutionalization was only marginally significant. Kin availability is measured by counts of sons, daughters, and unmarried children. Among older men, having more sons and having unmarried children were associated with a greater likelihood of subsequent co-residence, but none of the three kin availability variables were associated with institutionalization or mortality risk.

In Models 2 and 3 of Table 4.3, sentinel health events and poor functional status were specified as time-varying health measures that were expected to increase the likelihood of subsequent transitions out of living alone. It was found that life-threatening conditions, past hospitalizations, and fall history did not affect older men's risk of transitioning to co-residence. However, in Model 2 when ADLs and IADLs were not specified, older men who experienced two or more falls in the past two years were about three times more likely than men with no recent falls to enter an institution, while the relative risk of institutionalization was 106% higher for men with one or more injurious falls. Lastly, life-threatening conditions, hospitalization, and falls reported at the beginning of a survey interval were associated with an increased risk of subsequent death among these older men within two years.

Functional status measures of self-reported counts of ADLs and IADLs at the beginning of each survey interval were specified as additional risk factors in Model 3. This model included measures of ADLs and IADLs reported at the beginning of survey intervals. Model 3 results clearly show the statistically significant effects of increases in ADLs and IADLs on subsequent institutionalization and death controlling for sentinel events. However, ADLs and IADLs were not associated with the relative risks of co-

residence, IADLs were associated with a greater relative risk of institutionalization, and both ADLs and IADLs were associated with higher relative risks of mortality. These time-varying functional status measures were found to largely mediate the effects of fall history on the risks of subsequent institutionalization and death. The respective estimated effects of multiple falls on death and injurious falls on institutionalization or death were reduced to statistical insignificance. After considering ADLs and IADLs in Model 3, life-threatening conditions and hospitalizations were still associated with greater risk of subsequent death among older men living alone. In contrast, with the exception of a substantial increase in risk of institutionalization among older men with multiple falls, there were relatively weak associations between other sentinel events and risks of subsequent co-residence and institutionalization.

In Model 4, controls for cognitive and emotional health, health behaviors, and social network were added. All were specified as time-varying variables. Noticeably, none of these control variables were associated with the likelihood of subsequent co-residence. Cognitively impaired men were more than four times as likely to enter an institution as otherwise similar men who were cognitively intact. Somehow, having relatives living in the neighborhood increased older men's risk of institutionalization. Higher levels of BMI were associated with a lower mortality risk, while being a current smoker increased mortality risks. Lastly, the specification of additional control variables in Model 4 had relative modest impacts on the estimated effects of sentinel health events and functional status along with other variables described above, with only modest reductions in the magnitude of estimated relative risk ratios and their statistical significance.

Table 4.3. Results of Multinomial Discrete-time Event History Analyses for Older Men Who Have Lived Alone: 1998-2012

	Model 1			Model 2		
	Cores.	Inst.	Death	Cores.	Inst.	Death
Time living alone[a]	0.88**	1.12*	1.11**	0.87**	1.10*	1.10*
Late entrants (1=yes)	0.87	1.15	1.17	0.87	1.19	1.24
Marital status at the start of living alone[b]						
Separated or divorced	0.90	1.00	1.11	0.92	1.02	1.18
Never married	0.62	1.17	1.12	0.63	1.27	1.25
Age at the start of living alone[c]	1.00	1.09***	1.07***	1.00	1.08***	1.07***
Race and ethnicity[d]						
Black	1.07	0.61	1.02	1.11	0.75	1.20
Hispanic	2.34***	0.36	0.70†	2.38***	0.39	0.86
Year of education	0.99	1.00	1.00	0.99	1.00	1.01
Personal income (Ln)	1.12	0.83**	0.83***	1.13†	0.84*	0.85**
Net worth (Ln)	1.00	0.90***	0.94**	1.01	0.91***	0.95*
Homeownership	1.04	0.67*	0.69***	1.03	0.69†	0.69**
Number of sons	1.09†	1.00	0.99	1.09†	0.98	0.98
Number of daughters	0.99	0.87†	0.99	1.00	0.87†	0.99
Number of unmarried children	1.15*	0.92	0.94	1.16*	0.93	0.95
Number of fatal conditions (0-6)				1.06	1.12	1.29***
Number of hospitalizations[e]						
1				0.94	1.33	1.47**
2 and more				1.17	1.41	2.11***
Fall history[f]						
1				1.28	1.60	1.52*
2 and more				1.32	2.98***	1.50**
Injurious falls				1.05	2.06*	1.38*
ADLs (0-5)						
IADLs (0-5)						
Cognitive impairment (1=yes)						
Emotional problems (1=yes)						
Heavy drinker (1=yes)						
Current smoker (1=yes)						
Body mass index						
Proximate children (1=yes)						
Near relatives (1=yes)						
Near friends (1=yes)						
Intercept	0.03**	0.00***	0.01***	0.03**	0.00***	0.01***
Pseudo R-square	0.0613			0.0837		

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 4,290. †$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Reference group: widowed

[c] Time-invariant

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

Table 4.3. Results of Multinomial Discrete-time Event History Analyses for Older Men Who Have Lived Alone: 1998-2012 (*Continued*)

	Model 3			Model 4		
	Cores.	Inst.	Death	Cores.	Inst.	Death
Time living alone[a]	0.87**	1.09*	1.10*	0.87**	1.09*	1.11**
Late entrants (1=yes)	0.87	1.17	1.22	0.87	1.24	1.18
Marital status at the start of living alone[b]						
Separated or divorced	0.92	1.05	1.19	0.92	1.08	1.11
Never married	0.63	1.32	1.25	0.62	1.10	1.17
Age at the start of living alone[c]	1.00	1.08***	1.06***	1.00	1.08***	1.06***
Race and ethnicity[d]						
Black	1.12	0.81	1.25	1.10	0.81	1.26
Hispanic	2.39***	0.45	0.85	2.35***	0.41	1.00
Year of education	1.00	1.02	1.02	1.00	1.06	1.02
Personal income (Ln)	1.13†	0.85*	0.86**	1.12†	0.87*	0.88*
Net worth (Ln)	1.01	0.93**	0.97†	1.01	0.93**	0.98
Homeownership	1.03	0.70†	0.69***	1.03	0.70†	0.69**
Number of sons	1.09†	1.00	0.99	1.10*	1.02	1.00
Number of daughters	0.99	0.86†	0.99	1.00	0.90	1.03
Number of unmarried children	1.15*	0.93	0.93	1.15*	0.90	0.91
Number of fatal conditions (0-6)	1.05	1.09	1.25***	1.04	1.07	1.28***
Number of hospitalizations[e]						
1	0.94	1.33	1.46**	0.93	1.32	1.49**
2 and more	1.16	1.30	1.95***	1.16	1.23	1.99**
Fall history[f]						
1	1.28	1.49	1.45†	1.27	1.59	1.41†
2 and more	1.30	2.44***	1.28	1.27	2.37**	1.28
Injurious falls	1.02	1.50	1.08	1.00	1.50	0.99
ADLs (0-5)	1.01	1.05	1.21**	1.01	1.09	1.23**
IADLs (0-5)	1.08	1.59***	1.24**	1.04	1.38**	1.16*
Cognitive impairment (1=yes)				1.57	4.05***	1.35
Emotional problems (1=yes)				1.13	1.08	1.12
Heavy drinker (1=yes)				0.98	0.51	1.07
Current smoker (1=yes)				0.82	1.25	1.75**
Body mass index				1.01	1.03	0.94***
Proximate children (1=yes)				0.95	0.71	0.90
Near relatives (1=yes)				0.90	1.35*	0.91
Near friends (1=yes)				0.95	0.90	0.81
Intercept	0.02***	0.00***	0.03***	0.02**	0.00***	0.01***
Pseudo R-square	0.0945			0.1085		

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 4,290. †$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Reference group: widowed

[c] Time-invariant

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

Women's Transitions from Living Alone

Table 4.4 contains the empirical results for older women for the same four models that were specified for older men. Similar to their male counterparts, Table 4.4 shows that as the duration of living alone increased, the relative risks of women's transitioning to co-residence decreased, and their relative risks of entering an institution or dying increased. However, the relative risk of subsequent institutionalization for women increased by more than 20% for each additional period of living alone, an amount that was twice as high as that found for men (see Models in Table 2 earlier).

Similar to men, an older woman's marital status at the start of living alone did not appear to have an impact on subsequent transitions of living arrangements, while the age at the start of living alone was strongly associated with increased risks of subsequent institutionalization and death. While never having married was associated with a higher mortality risk before controlling for economic resources and kin availability (not shown), marital status was not found to be associated with the transitions from living alone once these factors were specified in the models. As it was for men, the late entrant indicator detected no statistically significant difference between women who began living alone prior to baseline and women who began living alone during the study period.

Table 4.4 also shows that the effects of race and ethnicity, economic resources, and kin availability for older women were slightly different from those for older men. Whereas older Hispanic men who were more likely than their non-Hispanic White counterparts to transition to co-residence, there were not statistically discernible racial/ethnic differences in the risk of subsequent co-residence among older women.

Despite that, minority women were found to have much lower likelihoods of subsequent institutionalization than their non-Hispanic White counterparts. The gendered differences in racial or ethnic patterns of living arrangement transition risks may suggest racial or ethnic differences in offering support to one's parents and the potentially different pathways taken by men and women to live alone. Economic resources exhibited somewhat different influences on subsequent transitions of older women who were living alone than for their male counterparts. Educational levels were significantly associated with a higher relative risk of subsequent institutionalization for older women. While not anticipated, a similar result was also found in at least one other study (Muramatsu et al., 2007). For older women, only non-housing assets were associated with a lower relative risk of co-residence, while both personal income and non-housing assets were negatively associated with the relative risk of subsequent institutionalization. Similar to older males, female homeowners were less likely to enter an institution or die subsequently while living alone. Kin availability was also as crucial for co-residing subsequently for women as it was found to be for men. The numbers of sons and daughters were marginally associated with the relative risk of subsequent co-residence among women, while the number of unmarried children was a particularly important factor, with a 13% greater relative risk of co-residence for each additional unmarried child.

Models 2 and 3 of Table 4.4 considered the potential effects of older women's sentinel health events on subsequent transitions of living arrangements. After controlling for ADLs and IADLs, multiple hospitalizations (marginally) and falls were associated with increased risk of subsequent co-residence. Sentinel health events, and in particular having multiple hospitalizations and falls, were associated with increased risks of

subsequent institutionalization. On the other hand, life-threatening conditions and hospitalizations were strongly associated with increased relative mortality risks. Similar to older men, the inclusion of ADLs and IADLs muted the effects of injurious falls on subsequent institutionalization risk, but injurious falls were still associated with a lower mortality risk.

The overall patterns of the findings for functional status for older women were fairly similar to those found among older men. In general, ADLs and IADLs are strong predictors for subsequent transitions in women's living arrangements. Results from Model 3 suggest that increases in IADLs are associated with greater risks of subsequent co-residence and institutionalization, and that increases in ADLs and IADLs are both positively associated with a greater likelihood of death among women. When additional control variables are added in Model 4, ADLs and IADLs were no longer associated with subsequent co-residence, while the effects of ADLs and IADLs on institutionalization and death remained the same. Analyses not shown suggest that the specification of cognitive impairment is likely responsible for the insignificant effects of IADLs on co-residence in full Model 4.

Regarding other control variables in Model 4 of Table 4.4, women living alone who experienced emotional problems are suggested to be particularly vulnerable to subsequent institutionalization and death, while those having relatives or friends in their neighborhood were found to have lower relative risks of transitioning out of living alone. Cognitive impairment was associated with higher relative risks of co-residence (marginally), institutionalization and death at the subsequent wave. Similar to their male counterparts, female smokers were more likely to die subsequently, but having higher

levels of BMI was found to be protective against mortality risks among women living alone. Unlike their male counterparts, those women who were diagnosed with emotional problems were more likely to be institutionalized or die. In addition, women who had friends living nearby had a lower relative risk of subsequent co-residence, and having relatives living nearby reduced the relative risks of subsequent institutionalization and death.

In analyzing older men's and women's transitions out of living alone, consistent time patterns and age effect of living alone on subsequent transitions were observed among older men and women. The effects of race or ethnicity, economic resources, and kin availability were generally as expected. However, over the duration of living alone, whereas none of the sentinel health events (i.e. life-threatening conditions, hospitalizations, and falls) increased men's risks of transitioning to co-residence, multiple hospitalizations or falls were found to trigger such transitions for women. For both men and women, the ADLs and IADLs reported over the duration of living alone were also unrelated to subsequent co-residence. The effects of sentinel health events that occurred prior to the wave interview date on subsequent transitions were partially mediated by the addition of these functional status measures that were reported at the interview. However, experiencing multiple hospitalizations or falls prior to the current interview retained direct effects on the risks of entering an institution and/or dying at the subsequent wave. Because these variables were specified as time-varying in models reported in Tables 4.3 and 4.4, the findings discussed above represent the effects of changes in these sentinel health events and functional status variables which occur over the duration of the period of living alone.

As the effects of cultural preference and kin availability mostly remained unchanged, and economic resources were relatively stable, it is puzzling that the changes in health did not seem to trigger older men and women's actual movements to living with someone, as health changes were clearly shown to have effects on institutionalization and death. In the next analyses, I turn the attention to health changes that are measured concurrently with subsequent transitions to co-residence, institutionalization, and death.

Table 4.4. Results of Multinomial Discrete-time Event History Analyses for Older Women Who Have Lived Alone: 1998-2012

	Model 1			Model 2		
	Cores.	Inst.	Death	Cores.	Inst.	Death
Time living alone[a]	0.89***	1.27***	1.17***	0.88***	1.25***	1.14***
Late entrants (1=yes)	0.85	1.10	1.02	0.86	1.13	1.08
Marital status at the start of living alone[b]						
Separated or divorced	1.08	0.81	1.02	1.08	0.81	1.06
Never married	0.97	1.00	1.22	0.99	1.09	1.37†
Age at the start of living alone[c]	1.01†	1.12***	1.09***	1.01†	1.12***	1.09***
Race and ethnicity[d]						
Black	1.18	0.64*	1.02	1.19	0.69*	1.11
Hispanic	1.18	0.41**	0.95	1.21	0.47*	1.30†
Year of education	1.00	1.03	0.99	1.00	1.04†	1.00
Personal income (Ln)	0.98	0.83***	0.93†	0.98	0.82***	0.94
Net worth (Ln)	0.95**	0.93***	0.96**	0.96**	0.94***	0.98†
Homeownership	1.08	0.60***	0.72***	1.10	0.64***	0.80**
Number of sons	1.05†	0.99	0.96	1.05†	0.98	0.94*
Number of daughters	1.05*	0.97	0.96	1.05*	0.96	0.92*
Number of unmarried children	1.13**	0.92†	1.00	1.13**	0.92†	1.01
Number of fatal conditions (0-6)				1.04	1.17**	1.68***
Number of hospitalizations[e]						
1				0.94	1.26†	1.44***
2 and more				1.30*	1.88***	2.05***
Fall history[f]						
1				1.09	1.16	1.02
2 and more				1.29*	1.75***	1.22*
Injurious falls				1.05	1.40*	1.00
ADLs (0-5)						
IADLs (0-5)						
Cognitive impairment (1=yes)						
Emotional problems (1=yes)						
Heavy drinker (1=yes)						
Current smoker (1=yes)						
Body mass index						
Proximate children (1=yes)						
Near relatives (1=yes)						
Near friends (1=yes)						
Intercept	0.08**	0.00***	0.00***	0.07**	0.00***	0.00***
Pseudo R-square	0.0706			0.0995		

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 12,993. †$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Reference group: widowed

[c] Time-invariant

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

Table 4.4. Results of Multinomial Discrete-time Event History Analyses for Older Women Who Have Lived Alone: 1998-2012 (*Continued*)

	Model 3			Model 4		
	Cores.	Inst.	Death	Cores.	Inst.	Death
Time living alone[a]	0.88***	1.23***	1.13***	0.88***	1.22***	1.13***
Late entrants (1=yes)	0.85	1.13	1.07	0.87	1.16	1.03
Marital status at the start of living alone[b]						
Separated or divorced	1.07	0.78	1.03	1.05	0.73	1.00
Never married	0.98	1.04	1.32	1.00	1.00	1.35†
Age at the start of living alone[c]	1.01	1.10***	1.08***	1.01	1.10***	1.08***
Race and ethnicity[d]						
Black	1.19	0.69*	1.07	1.22†	0.67*	1.20
Hispanic	1.17	0.41**	1.12	1.19	0.41**	1.20
Year of education	1.01	1.06**	1.02	1.01	1.08***	1.02
Personal income (Ln)	0.98	0.83***	0.95	0.99	0.85**	0.97
Net worth (Ln)	0.96**	0.95**	0.99	0.96**	0.95***	0.99
Homeownership	1.11	0.66***	0.82*	1.13	0.66***	0.84*
Number of sons	1.05†	0.99	0.95*	1.05†	1.00	0.96
Number of daughters	1.05*	0.95	0.91*	1.05†	0.96	0.92†
Number of unmarried children	1.13**	0.93	1.02	1.13**	0.92	1.01
Number of fatal conditions (0-6)	1.03	1.11†	1.59***	1.03	1.12†	1.63***
Number of hospitalizations[e]						
1	0.93	1.21	1.37***	0.94	1.22†	1.38***
2 and more	1.25†	1.63**	1.80***	1.25†	1.63**	1.79***
Fall history[f]						
1	1.08	1.15	1.01	1.08	1.15	1.01
2 and more	1.24*	1.43*	1.02	1.23*	1.39*	1.02
Injurious falls	1.01	1.13	0.81†	0.99	1.08	0.77*
ADLs (0-5)	1.04	1.07	1.19***	1.05	1.12†	1.24***
IADLs (0-5)	1.12*	1.57***	1.39***	1.06	1.33***	1.27***
Cognitive impairment (1=yes)				1.48†	3.29***	1.73***
Emotional problems (1=yes)				1.17	1.47**	1.23†
Heavy drinker (1=yes)				1.10	0.93	1.37
Current smoker (1=yes)				1.18	1.14	2.19***
Body mass index				1.00	0.98	0.95***
Proximate children (1=yes)				1.02	0.91	1.00
Near relatives (1=yes)				0.94	0.81*	0.82*
Near friends (1=yes)				0.79**	0.89	0.89
Intercept	0.07**	0.00***	0.00***	0.08**	0.00***	0.00***
Pseudo R-square	0.1166			0.1283		

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 12,993. †$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Reference group: widowed

[c] Time-invariant

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

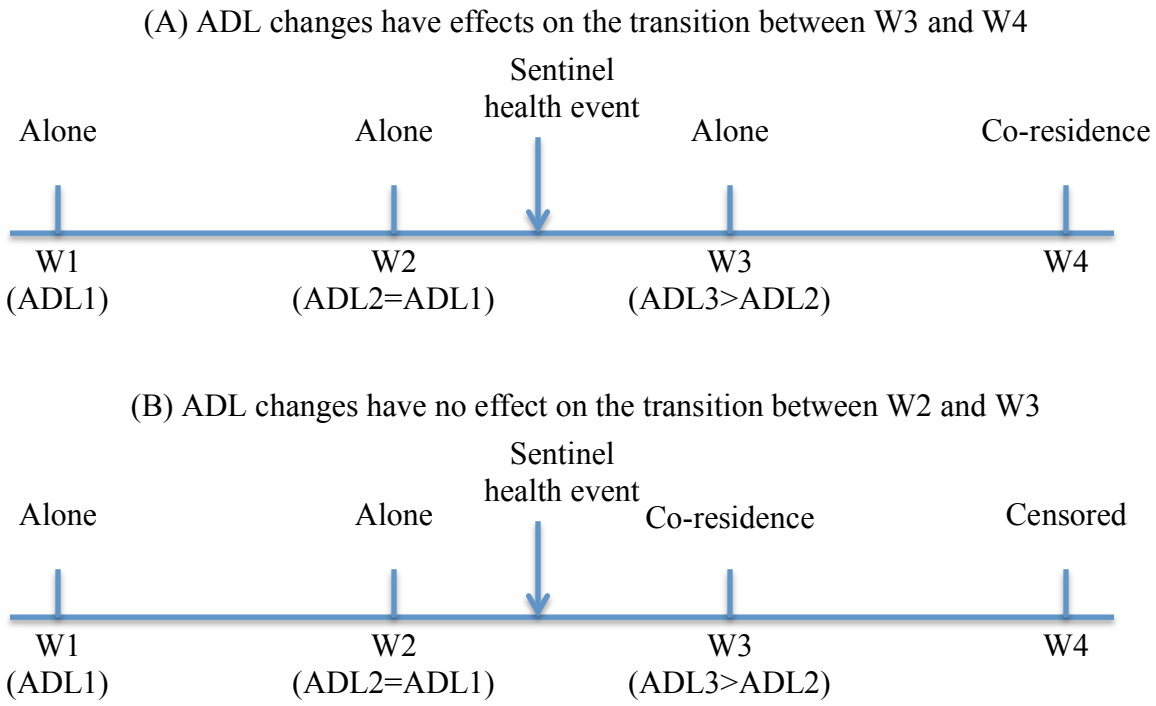
Concurrent Changes in Functional Status and Living Arrangements

Having shown the strong effects of time-varying sentinel health events and functional status on subsequent death, the following analyses examine whether some effects of sentinel health events and functional status might be reflected in subsequent increases in ADLs and IADLs that are measured concurrently over the same time interval during which transitions in living arrangements to co-residence or institutionalization are measured. Indeed, the empirical results show some evidence that the effects of falls and hospitalizations on subsequent transitions out of living alone were partially mediated by specification of time-varying ADLs and IADLs. However, this specification of ADLs and IADLs as time-varying covariates cannot capture any immediate consequences that worsened functional status might have on individuals who make a living arrangement transition before the first interview that follows the sentinel health events.

Consider an older person who was living alone at the last survey interview and experiences a fall that results in a hospitalization for a hip fracture and who was discharged from the hospital to live with a child rather than returning to his or her home. Figure 4.2 illustrates two examples of possible associations between ADL changes and living arrangement transitions. Graph A of Figure 4.2 shows that the older person experiences a substantial decline in functional status between wave 2 and 3, which is potentially caused by the sentinel health events that occurred during the same survey interval. However, the actual transition in living arrangement from living alone to co-residence occurs between wave 3 and wave 4. The influence of sentinel health events is actually partially reflected through the time-varying functional status, as it has been shown in the empirical results earlier. Note that although sentinel health events by

themselves had limited effects on co-residence, controlling for functional status, these health incidents retained the direct effects on subsequent institutionalization and death.

Figure 4.2. Two Examples of Models without Concurrent ADL Changes



Graph B of Figure 4.2 shows another scenario in which this older person changes the living arrangements immediately after the occurrence of sentinel health events before the next survey interview at wave 3. In this example, the factors that precipitated the abrupt living arrangement transition occurred concurrently during the same survey interval over which the living arrangement was made. Since the person would no longer be living alone at wave 3, and the co-residence at wave 3 would be treated as the event occurrence, discrete-time event history models or any transition-based analyses would only model the experience of living alone, sentinel health events, and functional status

prior to wave 3. The effects of the sentinel health events and associated increased in ADLs and/or IADLs which actually precipitated the older person's transition out of living alone would not be captured in the model parameter estimates. This is because transitions are measured from the beginning interval of living alone, and the described sentinel health events and functional status change occurred after the last survey interview in which the older person was known to be living alone.

As is shown in Graph B of Figure 4.2, sentinel health events that occur concurrently with the transitions between wave 2 and 3 can directly impact the decision of living arrangement transitions over the same period of time. These effects were partially mediated through the changes of functional status that are concurrent with the living arrangement transition between two interview dates. In the following analyses, the study focuses on the concurrent changes in functional status that could also occur concurrently with living arrangement transitions.

Concurrent increases in ADLs and IADLs can occur in addition to the overall changes in the same measures that reflect functional status changes during the time spent living alone. Changes in ADLs and IADLs that are concurrent with subsequent transitions in living arrangements can potentially capture abrupt changes in functional status during the period of living arrangement transitions that were not possible to capture with the time-varying counts of ADLs and IADLs measured at the beginning of each survey interval over which transitions ware measured. Consistent with the conceptualization of the disablement process, onset of life-threatening conditions, past hospitalizations, and fall history are the remote influences in the pathology phase. These influences may develop over time and result in subsequent changes in ADLs or IADLs

that trigger actual changes in living arrangements. As some studies have suggested (Speare, Avery, & Lawton, 1991; Worobey & Angel, 1990), living arrangement transitions may occur relatively quickly in response to abrupt changes in health. While time-varying measures may convey the patterns and trajectories of health changes over the entire study period, most studies did not consider concurrent changes in health (See Wolinsky et al., 1993; Pricket & Angel, 2015). As described in the literature, applying concurrent changes in health implicitly assumes that the health changes occur prior to the transitions in living arrangements, but it is not possible to examine the actual time order of the two events. This issue is revisited in the discussion.

To examine the potential effects of concurrent increases in ADLs and IADLs between the current time and the subsequent interview, person-period observations of respondents who died or who were nonrespondents at the subsequent waves had to be dropped out from the analysis sample because the health status at the time of death or nonresponse was not available. Only those observations with available ADLs and IADLs at the subsequent waves could be retained in the following analyses. The last observations of 711 men (16.6%) and 1,558 women (12.0%) were removed from the estimation for the following analyses because of subsequent death or nonresponse.

Tables 4.5 and 4.6 contain the empirical results for models with variables measuring concurrent increases in ADLs and IADLs as well as the other covariates specified in Model 4 in Tables 4.3 and 4.4 reported earlier. The following tables report relative risk ratios of concurrent increases in ADLs and IADLs between the beginning and end of survey intervals with respect to the overall changes in the same measures during the time spent living alone. Although excluding observations of death or

nonresponse may potentially cause biased estimates of hazards of subsequent transitions, any biases appeared to be modest. Among common variables, the estimated relative risk ratios for variables in Tables 4.5 and 4.6 did not appear to differ much from those in Tables 4.3 and 4.4. The omitted observations of continued living alone presumably contributed information used more to estimate the likelihood of mortality or were treated as censored, instead of contributing to estimating the likelihood of transitioning to co-residence or institutionalization.

Table 4.5 shows that for older men, the duration of living alone was not associated with institutionalization risks, and that the once strong effect of multiple falls on institutionalization was largely reduced to insignificance after considering concurrent changes in ADLs and IADLs. While neither the overall ADL/IADL change nor the concurrent ADL increase had a significant impact on older men's probabilities of subsequent co-residence, older men who had a concurrent increase of two or more IADLs were 138% more likely to have such transitions relative to otherwise identical men having no change or a concurrent decrease in IADLs over the transition time interval. Although the overall ADL change was unrelated to institutionalization, the relative risk of subsequent institutionalization was about 2.5 times higher for men with a concurrent increase in one ADL, and 8.8 times higher for those with a concurrent increase of two or more ADLs than men having no change or concurrent improvement in ADLs. In addition to the overall IADL change over the duration of living alone on an elevated institutionalization risk, the relative risk of institutionalization for men having a concurrent increase in two or more IADLs was 8.8 times higher than men having no change or concurrent improvement in IADLs.

Older men who were living alone were unlikely to transition to co-residence given the onset of prior sentinel health events or poor functional status. Given the overall patterns of IADLs changes, only a more catastrophic increase in IADLs may trigger the process of transitioning to co-residence. On the other hand, these findings also show that many subsequent institutionalizations were likely due to concurrent increases in ADLs or IADLs in addition to the already elevated institutionalization risk which resulted from the IADL increases over the duration of living alone. Institutionalization risk increases as older men's IADLs increase over the duration of living alone. Given the overall pattern, older men encounter even greater short-term abrupt increases in institutionalization risks when experiencing catastrophic increases in IADLs.

Table 4.5 Multinomial Discrete-time Event History Models for Subsequent Co-residence and Institutionalization among Older Male Survivors Who Have Lived Alone: 1998-2012

	Model 1		Model 2	
	Cores.	Inst.	Cores.	Inst.
Time living alone[a]	0.87**	1.08†	0.87**	1.02
Late entrants (1=yes)	0.90	1.33	0.88	1.22
Marital status at living alone[b]				
Separated or divorced	0.93	1.06	0.93	1.28
Never married	0.62	1.26	0.62	1.63
Age at living alone[c]	1.00	1.08***	1.00	1.06***
Race and ethnicity[d]				
Black	1.11	0.69	1.10	0.86
Hispanic	2.47***	0.46	2.50***	0.41
Year of education	1.00	1.07†	1.00	1.10*
Personal income (Ln)	1.11†	0.88†	1.12†	0.97
Net worth (Ln)	1.01	0.92**	1.01	0.94*
Homeownership	1.05	0.70†	1.06	0.61†
Number of sons	1.09†	1.01	1.09†	1.11
Number of daughters	1.00	0.89	0.99	0.86
Number of unmarried children	1.16*	0.91	1.17*	0.84
Number of fatal conditions (0-6)	1.05	1.09	1.05	1.04
Number of hospitalizations[e]				
1	0.93	1.20	0.93	1.16
2 and more	1.18	1.15	1.19	1.21
Fall history[f]				
1	1.29	1.50	1.30	1.74
2 and more	1.28	2.55***	1.26	1.66†
Injurious falls	1.01	1.51	1.00	1.10
ADLs (0-5)	1.00	1.08	0.97	1.21
IADLs (0-5)	1.05	1.38***	1.08	1.45***
Increase in ADL[g]				
1			0.61†	2.48**
2 and more			0.93	8.82***
Increase in IADL[h]				
1			0.90	1.61
2 and more			2.38***	8.80***

(*Table 4.5 continues*)

Table 4.5 Multinomial Discrete-time Event History Models for Subsequent Co-residence and Institutionalization among Older Male Survivors Who Have Lived Alone: 1998-2012 (*Continued*)

	Model 1		Model 2	
	Cores.	Inst.	Cores.	Inst.
Cognitive impairment (1=yes)	1.65	4.73***	1.51	2.99**
Emotional problems (1=yes)	1.12	0.99	1.09	0.99
Heavy drinker (1=yes)	0.96	0.47	0.98	0.43
Current smoker (1=yes)	0.82	1.16	0.81	1.09
Body mass index	1.01	1.03	1.02	1.04
Proximate children (1=yes)	0.96	0.72	0.95	0.65
Near relatives (1=yes)	0.91	1.42	0.92	1.50†
Near friends (1=yes)	0.95	0.90	0.97	0.95
Intercept	0.03**	0.00***	0.02**	0.00***
Pseudo R-square	0.0923		0.1677	

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 3,579. The same study sample was employed as that for Table 4.3, except for 771 person-period observations (16.6%) that were excluded due to death or nonresponse.

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Marital status at living alone indicates the martial status of the respondent at the start of living alone; Reference group: widowed

[c] Age at living alone is time-invariant, indicating the age of the respondent at the start of living alone.

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

[g] Reference group: no change or improved ADLs

[h] Reference group: no change or improved IADLs

Table 4.6 shows the empirical results containing variables measuring concurrent changes in ADLs and IADLs for older women. The once significant effects of sentinel health events on co-residence were muted, while the effects of multiple hospitalizations on institutionalization remained. The cumulative effects of overall ADLs/IADLs were strengthened when considering concurrent ADL/IADL increases among older women. Having IADL increases over the duration of living alone was associated with the relative risk of subsequent co-residence, while having increases in ADLs or IADLs was associated with relative risks of both co-residence and institutionalization. While having concurrent increases in ADL between the beginning and end of survey intervals was not associated with the likelihood of subsequent co-residence, the relative risks for subsequent co-residence were 1.6 times higher for women with a concurrent increase of one IADL, and 4.0 times higher for women with a concurrent increase of two or more IADLs than those having no change or concurrent improvement in IADLs. Relative to having no change or improved ADLs/IADLs, women having one concurrent increase in either ADLs or IADLs were about 80% more likely to enter an institution than otherwise similar women with no change or improved functional status. Moreover, relative to having no change or improved functional heath, the odds ratios for subsequent institutionalization were about 6.2 for women with a concurrent increase of two or more ADLs, and 8.2 for women with a concurrent increase of two or more IADLs.

Therefore, the results from Table 4.6 suggest that increases in IADLs over the duration of living alone and between survey intervals were both associated with greater likelihoods of subsequent co-residence, and that ADL changes were unrelated to the risk of co-residence among women in this study. Moreover, the overall ADL/IADL changes

as well as concurrent ADL/IADL increases were found to lead to greater risks of institutionalization, particularly among women who experienced recent catastrophic increases in ADLs or IADLs.

The concurrent changes in ADLs and IADLs further reduced the already weak association between prior sentinel events and subsequent transitions. For men, the duration of living alone was no longer associated with the risk of institutionalization, and having two or more falls was only marginally associated with subsequent institutionalization after considering concurrent changes in ADLs and IADLs. For women, the effects of the duration of living alone and multiple hospitalizations on institutionalization remained, but having multiple prior falls was no longer associated with subsequent institutionalization after concurrent ADL/IADL increases were included in the model. Inexplicably, having a concurrent increase in ADL for men and having a concurrent increase of two or more ADLs for women were associated with a lower risk for subsequent co-residence relative to continued living alone.

Table 4.6 Multinomial Discrete-time Event History Models for Subsequent Co-residence and Institutionalization among Older Female Survivors Who Have Lived Alone: 1998-2012

	Model 1		Model 2	
	Cores.	Inst.	Cores.	Inst.
Time living alone[a]	0.88***	1.23***	0.87***	1.13**
Late entrants (1=yes)	0.86	1.15	0.84†	1.09
Marital status at living alone[b]				
Separated or divorced	1.04	0.76	1.02	0.76
Never married	1.01	1.05	1.00	0.92
Age at living alone[c]	1.01	1.11***	1.00	1.07***
Race and ethnicity[d]				
Black	1.21†	0.63*	1.17	0.63*
Hispanic	1.19	0.34**	1.21	0.32**
Year of education	1.01	1.08***	1.01	1.09***
Personal income (Ln)	0.98	0.83**	1.00	0.90*
Net worth (Ln)	0.96**	0.95***	0.96**	0.97*
Homeownership	1.13	0.66***	1.12	0.59***
Number of sons	1.06*	0.99	1.06†	1.00
Number of daughters	1.05†	0.96	1.04	0.92
Number of unmarried children	1.13**	0.93	1.14**	0.93
Number of fatal conditions (0-6)	1.03	1.11†	1.00	1.00
Number of hospitalizations[e]				
1	0.93	1.24†	0.93	1.22
2 and more	1.23†	1.59**	1.19	1.53**
Fall history[f]				
1	1.07	1.23	1.06	1.12
2 and more	1.23*	1.46*	1.15	1.20
Injurious falls	1.00	1.05	0.97	0.86
ADLs (0-5)	1.05	1.13†	0.99	1.24**
IADLs (0-5)	1.07	1.34***	1.16**	1.50***
Increase in ADL[g]				
1			0.91	1.83**
2 and more			0.77†	6.23***
Increase in IADL[h]				
1			1.55**	1.85**
2 and more			3.98***	8.24***

(*Table 4.6 continues*)

Table 4.6 Multinomial Discrete-time Event History Models for Subsequent Co-residence and Institutionalization among Older Female Survivors Who Have Lived Alone: 1998-2012 (*Continued*)

	Model 1		Model 2	
	Cores.	Inst.	Cores.	Inst.
Cognitive impairment (1=yes)	1.60†	3.92***	1.23	2.26***
Emotional problems (1=yes)	1.19†	1.48*	1.14	1.29†
Heavy drinker (1=yes)	1.12	0.88	1.17	1.14
Current smoker (1=yes)	1.17	1.17	1.19	1.16
Body mass index	0.99	0.97†	1.00	0.99
Proximate children (1=yes)	1.02	0.96	1.01	0.87
Near relatives (1=yes)	0.95	0.78*	0.94	0.71**
Near friends (1=yes)	0.77**	0.93	0.78**	1.06
Intercept	0.09**	0.00***	0.09**	0.00***
Pseudo R-square	0.1105		0.1856	

Note: All values are weighted for adjusting complex sampling design. The number of person-period observations is 11,435. The same study sample was employed as that for Table 4.4, except for 1,558 person-period observations (12.0%) that were excluded due to death or nonresponse.

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

[a] Time living alone is time-varying, indicating the number of intervals since the respondent was observed living alone until a transition or being censored.

[b] Marital status at living alone indicates the martial status of the respondent at the start of living alone; Reference group: widowed

[c] Age at living alone is time-invariant, indicating the age of the respondent at the start of living alone.

[d] Reference group: non-Hispanic white

[e] Reference group: no hospitalizations in the past two years

[f] Reference group: no falls in the past two years

[g] Reference group: no change or improved ADLs

[h] Reference group: no change or improved IADLs

Although not reported here, sensitivity analyses were conducted to examine the validity of these findings. The potential influences on the risk of subsequent institutionalization from having relatively few occurrences of concurrent increases of two or more ADLs/IADLs were considered. Instead of distinguishing one ADL/IADL increase and two or more ADL/IADL increases, having any ADL/IADL increase was used to test whether the large relative risk ratios of subsequent institutionalization were a consequence of rare events, or relatively low incidence of having a concurrent increase of two or more ADLs/IADLs. Results showed that men's relative risk ratios for institutionalization were only slightly reduced, and that women's odds ratios for institutionalization were reduced by half. The effects of having any ADL/IADL increase did not distribute toward that of having two or more ADL/IADL increases. In addition to this sensitivity analysis, a second sensitivity analysis was performed. Random subsamples excluding 50%, 75%, and 90% of those having no transitions were used to proportionally increase the occurrence of subsequent institutionalization in the overall sample. Because the reduced samples possessed a better balance in the proportion of institutionalized observations to the overall sample, this should reduce the potential influence of having relatively few occurrences of institutionalization. Results showed that for men and women, the relative risk ratios for concurrent ADL increases were generally the same, while the relative risk ratios for concurrent IADL increases were even larger as the sample size decreased, particularly among men. The likelihood of transitions is more sensitive to the concurrent increases in IADLs. The above two sensitivity analyses suggested that the large odds ratios of having a concurrent increase of two or more ADLs/IADLs on subsequent institutionalization were not caused by either the low

prevalence of having an increase of two or more ADLs/IADLs or the relatively few occurrences of subsequent institutionalization.

Discussion

The current study examined a full range of measures as specified in the rational choice model and additional indicators of past influences and potential confounders among older men and women who were living alone between 1998 and 2010.
Older persons who were observed living alone had poorer kin availability, as measured by the number, marital status, and residential proximity of their children, relative to those who were never observed living alone. Even among this older subpopulation with more limited kin resources, fewer unmarried children was associated with a lower likelihood of co-residence. Economic resources prevent older persons living alone from entering an institution, and potentially lower their risk of mortality. Sentinel health events and functional status have complicated influences on subsequently entering an institution or dying, while catastrophic increases in ADLs or IADLs that occur concurrently with living arrangement transitions were found to have strong effects in triggering transitions to co-residence and, to a greater extent, to institutionalization.

The current study found that the relative risk of transitioning to co-residence declines with increased duration of living alone, while the relative risks of institutionalization and death increase for each additional period of living alone. This result is consistent with findings from Mutchler (1992) and Wilmoth (1998). New insights are provided from the current study. First, in our discrete-time data, the relative risks of transitioning to co-residence and institutionalization/death changed in the opposite direction at a relatively comparable pace. Women, in particular, were at elevated

risk of institutionalization for each additional period living alone, controlling for economic resources, kin availability, health, and additional variables. Second, the age at the start of living alone exhibits generic risks for institutionalization and death. The older a person, man or woman, is when beginning to live alone, the greater the risk of entering an institution or dying at the subsequent wave, after controlling for the time spent living alone and other effects.

The marital status at the start of living alone reflects the past marital history and differential availability of potential candidates of co-residence in the future (Aquilino, 1990; Pezzin, Pollask, & Schone, 2008). Prior research also suggests a short-term increase of mortality risk for the newly widowed due to bereavement (Nihtila & Martikainen, 2008; Strohschein, 2011). However, the results of the current study clearly demonstrate that the pathways entering living alone are not related to relative risks of co-residence, institutionalization, or death, once economic resources and kin availability are controlled.

In the current study, the influences of race and ethnicity vary by gender and operate as the opportunity for co-residence for men, and as the resources to avoid institutionalization for women. Older Hispanic men were much more likely to co-reside with someone subsequently, compared to non-Hispanic whites, while black or Hispanic women were found to have lower institutionalization risks. In addition to the normally poorer socioeconomic status, child-rearing norm and the experience of intergenerational co-residence in childhood have been citied for explaining co-residence among Blacks (Ruggles, 1994; Goldscheider & Lawton, 1998), while familistic values and immigration

history play critical roles in living arrangements among Hispanics (Burr & Mutchler, 1992; Van Hook & Glick, 2007).

The consistent protective effects of economic resources are shown against relative risks of institutionalization among men and women and of mortality among men, as has been shown in previous research (Mutchler & Burr, 1991). Because homeownership is specified separately, and net worth does not include housing value, the influence of homeownership was explicitly presented. Homeownership does not seem to offer the opportunity for subsequent co-residence or sustaining the current solitary status, but somehow it lowers the risks of institutionalization and death, possibly through the socioeconomic status, wealth management, and lifestyle that it conveys. The role of economic resources is less clear in the consideration of co-residence. Greater personal income for men and lower non-housing net worth for women were associated with the tendency for subsequent co-residence. While wealth may sustain women's solitary living arrangement, simply excessive person income is unlikely to allow older men to remarry or to live with children. Without further evidence, it is not possible to give a clear explanation. Nonetheless, personal income or non-housing net worth were associated with lower relative risks of institutionalization and/or death.

The availability of kin decides the options of alternative living arrangements that are available to men and women who are living alone. Because those who are living alone already had fewer children, their options for subsequent co-residence are inevitably limited. While the numbers of sons and daughters play a marginal role in subsequent co-residence, the number of unmarried children is decisive.

In the models in Tables 4.3 and 4.4, sentinel health events are measured over the previous two years or since the last survey wave interview. Since the specified functional status variables are measured at the time of the interview, these time-varying ADLs and IADLs measures will only reflect any immediate or short-term impacts of prior sentinel health events on the functional status at the time of the interview that follows these sentinel health events. Although sentinel health events and functional status were strongly associated with the mortality risk at the subsequent wave, these events were found to have limited direct effects on subsequent transitions to co-residence or institutionalization. Analyses applying concurrent changes of ADLs and IADLs confirmed that some of these effects operate indirectly through concurrent changes in functional status.

For men and women, the already weak influences of sentinel health events on the relative risk of subsequent co-residence were mediated by the concurrent increases in IADLs. The measures of IADLs that reflect the ability for household management appear to be most relevant in deciding subsequent co-residence among older persons, women in particular, who were living alone. Institutionalization risks remained elevated for men and women with multiple hospitalizations or falls prior to the present interview; however, one concurrent increase in ADLs or IADLs was associated with an increased risk of institutionalization, and catastrophic increases in ADLs or IADLs exhibited even greater risks for institutionalization. The mediation of sentinel health events by concurrent health changes is consistent with the disablement process proposed by Verbrugge and Jette (1994). The behavior change as manifested by living arrangement transitions in response to catastrophic disability is also supported by the general literature of rational choice model, late-life migration, and person-environment fit. Because the effects of concurrent

health changes are in addition to the overall change of the same measures over the duration of living alone, concurrent changes in health may capture the terminal drop of one's disability trajectory or unmeasured sentinel health events that occur concurrently with the living arrangement transitions.

The current study demonstrates the utility of functional status in understanding older persons' living arrangements. Sentinel health events may serve as a remote influence that initiates the consideration of living arrangement transitions. In contrast, part of the impacts of sentinel health events operate through the increases in physical disability that supposedly are more objective measures of independent living, as they reflect abilities for self-care and household managements. For this particular subgroup of older persons who are living alone, the current study found that among the health-related variables, only IADLs or IADLs that increase catastrophically trigger the process of transitions to co-residence. The effect does not seem large because the literature generally supports help-seeking behavior by sharing households between generations or with family members, and the study shows that those with declining health are more likely to enter an institution or die. It is possible that there are pre-determinants which may dominate the pathway of these older persons into solitary living arrangements and which are still at work in affecting their likelihood of making other co-residential living arrangement transitions. For some older parents, continuing to live alone may not be entirely due to their own preference to do so, but also partly due to intergenerational relationships and adult children's characteristics that have predetermined the status quo of living alone for these older persons. It is also likely that the longer the duration of living alone is, the more reluctant older persons are to share a household with any others

simply because of the difficulty associated with the transition itself or the challenge of accepting another person in their residence who would potentially diminish their privacy and autonomy.

Limitations

The results shown in the current study should be interpreted with acknowledgement of its limitations. Because of the nature of survey data, discrete-time event history models were employed for modeling the duration of living alone until the event occurrence of subsequent co-residence, institutionalization, or death. The exact time of these event occurrences is inevitably masked, as they are implicitly assumed to occur, if any at all, prior to the end of survey intervals or at the subsequent interview date. This particular situation may affect the substantive results because no transition occurring between the survey intervals is assumed, and short-term post-acute institutionalizations are mixed with long-term care residence in such institutions.

To ensure sufficient study sample, the current study includes late entrants whose time at which they began living alone was prior to the baseline. Although the current study managed to retrieve information regarding their successive status of living alone prior to the baseline, the information of some late entrants of the AHEAD cohort is incomplete because they may have been living alone before they were first observed in the HRS. In addition, the CODA respondents living alone at the baseline were not considered late entrants. Neither situation should bias the estimation by much, because some information on living alone for the AHEAD late entrants was obtained, and the age of the youngest CODA respondents who were living alone was close to the beginning of the risk set at the age of 65. The data manipulation strategy for left-truncated observation

was used among the AHEAD late entrants for whom the current study does not have complete histories of living alone. The insignificance of late entrant indicators provides support that the left-truncated observations with incomplete information do not appear to bias estimated relative risks for subsequent living arrangement transitions.

Although short-term health fluctuations after transitions to co-residence or institutionalization are likely, the concurrent changes in ADLs and IADLs are more likely to reflect the effects of functional status changes on living arrangement transitions because the overall pattern of functional status was controlled for, and prior sentinel health events were modeled. It is certainly possible that the concurrent increases in ADLs or IADLs were a consequence of a transition to co-residence or a nursing home. Past research has demonstrated that transitions to co-residence or institutionalization were more likely to be a social selection process where people with poor health tend to co-reside with someone or to enter an institution (Aneshensel, Pearlin, Levy-Storms, & Schuler, 2000; Davis, Moritz, Neuhaus, Barclay, & Gee, 1997; Magaziner, Cadigan, Hebel, & Parry, 1988). In their study of changes in disability and financial strain that were measured concurrently with the living arrangement transitions, Prickett and Angel (2015) examined the potential issue of reverse causation. They found that from their respondents living alone, co-residential living arrangement transitions were not predicted by changes in disability and financial strain. Given these supports, I am confident in the results of modeling concurrent health changes, while the potential limitation should be kept in mind.

Research on living arrangements in the past decade has mostly focused on the consequential effect of health on living arrangement transitions. Even though many

studies have still included related variables, few have drawn on the rational choice model as their theoretical background. It may be possible that kin availability related to the lower fertility among the older parents compared with the past cohorts may be not altered in short term, and economic recourses by personal accumulation and from the public sector may ensure a relatively sufficient status of resources. The role of health for older persons becomes more critical, since health may be relatively predictable in its development of disability or trajectory toward mortality or relatively unpredictable in sentinel health events that have profound influences on one's life course. The influence of health is particularly relevant in the era of increasing life expectancy and more marital dissolution in later life. Although men's increasing life expectancy may reduce the likelihood of women living alone in later life (Agree & Glaser, 2009), the instability of marriage in later life raises concerns about the feasibility of spousal caregiving as well as support from offspring (Pezzin, Pollak, & Schone, 2008; Shapiro, 2003), and it may not be surprising that the proportion of people living alone in later may not change by much as men and women depart from the once everlasting marriage to solitary living arrangements. Again, it is important to consider the life experience of living arrangements among those living alone.

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CHAPTER 5

CONCLUSION

The first objective of this dissertation study is to describe living arrangement histories of older adults over a 14-year period. The next objective is to examine the life course implications of being observed in different living arrangements. The final objective is to investigate the factors that initiate the transitions in living arrangement among older person who live alone. As individuals enter later life, we may observe a higher prevalence of older persons in the solitary arrangement of living alone. This study contributes to the literature by examining whether transitioning to other living arrangements is an adaptation for older adults living alone with increased need for care. Three major analyses were performed and reported in earlier chapters. These analyses aimed to address the three major research questions of this dissertation:

(1) Do older Americans' living arrangements exhibit a pattern of sequence?

(2) What are implications of a living arrangement status at a particular age on life expectancy?

(3) What are the factors that predict a transition out of a living alone arrangement by older Americans?

This chapter includes a summary of the specific study findings related to these research questions, a discussion of contributions of this research to the literature, a

discussion of future research directions, and lastly a discussion of the policy implications from the study results.

Summary of Findings

The first major research question of this dissertation was addressed via a descriptive analysis of living arrangement sequences of older persons contained in Chapter 2. This sequence analysis described in that chapter describes episodes of living arrangements, and, with techniques of optimal matching and cluster analysis, examines the patterns of living arrangement sequences observed over a 14-year period. For older persons, living with a spouse is shown to be the dominant living arrangement observed at the baseline, while the importance of living alone is also evident. Following the baseline living arrangements, men tend to either make no change or die subsequently, while women are more likely to depart for an intermediate living arrangement. Among those who made a transition, men and women tend to have intermediate living arrangements that are closely related to their baseline living arrangements. For the younger group of persons aged 65-74 years old, those coupled at baseline tend to live alone subsequently, whereas those living alone tend to live with someone—most likely a child—after departing from the solitary living arrangement. For those men and women aged 75 and older, living alone is still the likely living arrangement option following living with a spouse, but entering an institution is the most likely transition following living alone at baseline. Because older persons experienced, on average, no more than 3 episodes of living arrangements including death, the intermediate living arrangements appear to serve as stepping stones for older persons entering even older life from different respective prior living arrangements.

The descriptive findings are further confirmed by characterizing the general patterns of living arrangement sequences emerging from the sequence analysis methods that are closely related the baseline arrangements and, if any, intermediate arrangements. Index plots shows common sequence patterns—*Coupled*, *Deceased Spouse*, *Marital Disruption*, *Prolonged Living Alone*, and *Early Mortality*—that are distinct longitudinal patterns of living arrangement sequences in general. *Transitional Living alone*, *Living with Children*, *Mortality after Living with Children*, *Living with Others*, and *Institutionalization* are sequence patterns that are specific for a particular gender/age group. Older women exhibit more diverse living arrangements patterns than those for men, the finding that is potentially related to women's lower mortality risk and stronger connection to family members. In particular, living alone is found to be both the major living arrangements at the baseline or intermediately after baseline. Sequence analysis suggests that living alone can endure or extend until censored at the end of observed data. Additionally, the short-lived living alone episodes observed in other sequence patterns suggest that living alone is also a transient living situation in between major living arrangement episodes.

The second major research question regarding the implications of a living arrangement at different ages is addressed through MSLT analyses in Chapter Three. The average length of distinct living arrangements in one's life course is estimated with the multistate life table software, the Interpolated Markov Chain program (IMaCh). Transition probabilities among three living states and one absorbing state are estimated. Prevalence rates of each living arrangements implied by these transition probabilities are presented. Men's prevalence of co-residence is higher at younger ages and decline more

rapidly by age than women. Nevertheless, co-residence is still the most prevalent living arrangements for men at all ages. For men, the prevalence of living alone and institutionalization for men increases steadily with age, while women's prevalence rates of living alone increase with age until age 85, which coincides with the time when the prevalence of institutionalization begins to increase faster at the similar age. At age 80, women's prevalence of living alone exceeds that of co-residence; by age 95, institutionalization is the most prevalent living arrangement for surviving women.

Regarding the total life expectancy, men are expected to spend more time living alone or in an institution at older ages, while at any given ages, about half of women's remaining life is expected to be living alone along with a higher percentage of time in institutions than men. Status-based life expectancy shows more pronounced gender differences. For men, the gaps between status-based life expectancy for co-residence and that for living alone decreases with age. At age 85, male survivors who were living with someone or alone have no differences in their respective life expectancy. For female survivors, life expectancy for those living with someone or alone do not differ statistically from each other as early as at the age of 65, whereas at older ages, the differences emerges, suggesting a marginally higher life expectancy among women living alone than the co-residing women. These results should not be interpreted as supporting the health benefits of living alone; instead, based on the life table results and age patterns, it can only be concluded that treating living alone as a risk factor ignores the complex process of living arrangement dynamics.

Chapter Two found that living alone could be a transient state between major living arrangements or by itself an enduring state of living arrangements into even older

ages, and Chapter Three found evidence of extended time of living alone in men and women's life course, and no difference in life expectancies between those living alone and those living with someone. The fourth chapter is devoted to addressing the third major research question of the dissertation through an investigation on what factors trigger transitions out of living alone. Up to 14-years of living alone histories are modeled using the discrete-time event history analysis for subsequent transitions to co-residence, institutionalization, or death.

The fourth chapter begins with the review of the classic perspective of rational choice for living arrangements, and pays special attention to studies examining the triggering effects of health. Descriptive results show that, at baseline, men and women who are observed living alone during the period between 1998 and 2010 may not be in better health, and do not generally have more economic resources than those who are never observed living alone. Moreover, kin availability is shown to be more limited among those who have lived alone at some time relative to those who have never lived alone. Discrete-time results suggest the likelihood of subsequent co-residence declines with the time spent living alone, while the relative risks of institutionalization—women in particular—and death steadily increase over time. Economic resources are associated with lower risks of institutionalization or mortality, but these effects on transitioning to co-residence are less clear. The already limited availability of kin among those living alone indicates fewer potential opportunities available for subsequent co-residence; however, only the number of unmarried children is found to be decisive for co-residence. Considering the time-varying sentinel health events and functional status on subsequent transitions from living alone, rather weak associations are found with co-residence and

institutionalization, but strong impacts on mortality risks are evident. The study further considers changes in functional status that occur concurrently with living arrangement transitions during the same survey interval among a subgroup of survivors. Results show that the relative risks for co-residence and institutionalization are elevated for those experience concurrent increases in ADLs or IADLs, and more so for those with catastrophic declines in functional status regarding entering an institution. While limitations related to the unknown time order of functional decline and event occurrence are acknowledged, the current study demonstrates the potentially unmeasured effects of health changes that may be followed immediately by living arrangement transitions when concurrent changes are not considered. Given the few indicators that are found to increase the likelihood of subsequent co-residence, and the likelihood of subsequent co-residence inadvertently declines with time, the health change over time or concurrent with living arrangement transitions may indicate that older persons tend to depart from living alone through entering an institution or dying subsequently without making a change in their community living situation as they encounter health declines.

Contributions to the Literature

Although the contribution of the dissertation study to the literature of living arrangements appears to be primarily methodological, the substantive findings reveal new insights that would not have been evident without application of these methods. The methodological contribution of constructing between-wave status of living arrangements makes possible for the sequence analysis and multistate life table analysis because both are data-intensive techniques. In the sequence analysis, imputation considering the gap characteristics of missing between-wave living arrangement statues is conducted, and

pattern recognition techniques are employed for illustrating patterns of living arrangement sequences that are never shown in the literature. In the multistate life table analysis, further analyses utilizing interpolating Markov Chain approach for monthly transition probabilities allow for the age-specific estimations of the average lifetime spent in co-residence, living alone, and institutionalization for the overall population or by the living arrangement status at given ages. As the multistate life tables models bidirectional transitions, the current study is able to more accurately describe older persons' life course living arrangements among the very few studies that employ the same technique. In the discrete-time event history analysis, left truncated observations of living arrangement are addressed through the data manipulation strategy, and censored survival time is analyzed with event history models. Having considered the strong effect of health on mortality risk, the current study demonstrates that concurrent changes in functional status are likely to be a major factor responsible for triggering co-residence or institutionalization.

Future Directions

The results of this dissertation research provide more empirical evidence supporting the positive view of living alone, while implicit discovering some signs of health selection among older persons who live alone. Without directly investigating the negative view, which is beyond the scope of the dissertation study, we can only speculate that the positive image of those living alone may reflect the status of those who are capable to sustain living alone, while the negative characteristics of those living alone can be found among those who are in devastating situations without options of alternative living arrangements, or incapable of taking actions to make living arrangement transitions. Future studies should seek delicate research design for providing solid evidence of health

selection among those living alone. In particular, the differential effects of ADLs and IADLs would be addressed, as many studies have urged a composite measure of both (LaPlante, 2010; Porell & Miltiades, 2001). Alternatively, it may be achieved by developing a sound approach for simultaneously modeling disability trajectory and living arrangement transitions given the characteristics of available survey data (See Lillard & Waite, 1995; Tayler & Scott, 2004).

The other suggested future direction of research is largely around the issues related to the current longitudinal data of living arrangements, and how the limitations of the dissertation study can be addressed so that more research inquires can be examined. Essentially, the current study employs data that are longitudinal because of the time span of the panel and the extensive follow-ups among the respondents. However, the data are actually a collection of longitudinal follow-ups among respondents at different cross-sectional points in time over an extended period of time. The data collections at discrete survey intervals inevitably pose restrictions for analysis of transitions and time to event occurrence. In the sequence analysis, no transition is assumed between annual interview dates. In the MSLT analysis, monthly transition probabilities are estimated through the interpolated Markov Chains approach. In the discrete-time event history analysis, survival time is assumed to be discrete in the two-year survey intervals, and all events of subsequent living arrangements transitions are assumed to occur at the time immediately prior to the end of survey intervals.

In this dissertation study the consequences of this discrete nature of the survey data has been mitigated to some degree through approaches for addressing the limitations methodologically and conceptually. A better approach is to construct a full history,

indexed by month, of older persons' living arrangements by utilizing household members' self-reported time entering and exiting the household of older persons and identifying the time when an institutionalized respondents at the biennial interviews exit the institution. Similar work has been done for spells of community residence, post-acute nursing home stays, and long-term institutionalization in the Medicare Current Beneficiary Survey (Sato, Shaffer, Arbaje, & Zuckerman, 2011) or Medicare claims and nursing home Minimum Data Set (Intrator, Hiris, Berg, Miller, & Mor, 2011). Using the HRS to construct the monthly living arrangement data is very challenging. The extent to which it can be constructed depends on whether the household change data of household members do not conflict and can be coded in harmony, and whether institutionalization can be precisely recorded. A less challenging task that is still depended on data quality is to identify short-term institutionalization. Although, to the best knowledge, the HRS does not collect when an institutionalized person exit the institution, there might be related variables indicating the frequency, nights, and duration of nursing home stays from the subsequent interviews that can be used to determine whether the current institutionalization is not a long-term stay.

Policy Implications

Policy interventions are needed because the longer the older person live alone, the less likely he or she is able to transition to co-residence relative to entering an institution or dying without any change given the health decline. Although subtle preference and behavioral modifications may not be captured in the study results, the current study manages to illustrate the heterogeneity among those who are living alone. There are three policy implications that are drawn from evidence found in the dissertation study. First

and foremost, living alone should not be simply seen as a risk factor but a state that any older person may experience in their life course. Treating living alone a risk factor largely simplifies the heterogeneity of older persons in the solitary living arrangement and ignores the time dimension of living alone. Although co-residential living arrangements are most prevalent and enduring among older persons, living alone can be a transient or lengthy living arrangement that individuals are likely to experience sometime in later life. Orienting our view on living alone from seeing it at a single point in time to seeing it on the time axis that extends into the future will help to better allocate resources for those who have been long living alone and to target at those who may be at risk in the nearly future.

Second, policy interventions may be directed to provide counseling services that can help the older person and family members to better understand and evaluate the current statuses of the informal support network, the physical environment, and the older person's ability to self-sustain an independent household. Such counseling services can be integrated into part of the long-term care support and services that are already in place. Planning for living in the solitary living arrangement into older ages is no less important to planning for retirement. It is important to evoke the awareness of the benefits as well the costs that come with living alone for the older person who lives alone and the family members in his or her kin network, so that a better decision about living arrangement can be made. Most important of all, such evaluations should be carried out periodically on a continuous basis.

The third policy implication is related to the extent to which living situations might affect trajectories of health, and the long-term care services and support for older

persons. Seeking intergenerational support through co-residence does not seem likely in the face of sentinel health events and poor functional status. Presumably, co-residence can convey benefits or transfer supports that are not available in the solitary living arrangement, where it may come with conflicts with the household members and loss of independence. For older persons living alone, the design of long-term care policy may be directed to provide a broad range of services and support that are only subordinate to what can be provided by kin. Potentially, the supply of these services may mitigate the distress and health impacts that are associated with a particular living arrangement—such as living alone—and improve the health of older persons in general.

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APPENDIX A

CONSTRUCTING BETWEEN-WAVE LIVING ARRANGEMENT STATUS

Introduction

This report describes how to use HRS self-reported dates to create annual living arrangement transitions for the dissertation study. The main reason for proceeding with this approach is to deal with the sparse biennial transitions out of nursing home. In biennial living arrangement transitions, only a few respondents institutionalized at time 0 report their living arrangement status as living in the community at time 1. One way to inflate the number of biennial transitions for the analyses is to seek a shorter transition interval or annual transitions. Results from the annual transitions show that the number of transition out of nursing home does increase, whereas the percentage does not increase by much.

In the HRS, respondents are interviewed every two years or about 24 months. The HRS asks respondents about when they changed to the living arrangement status reported at the present biennial interview. Thus, we can take advantage of these self-reported dates and retrospectively construct the respondents' living arrangement status approximately one year prior to the present interview. Using the constructed between-wave status and the original HRS biennial status, we can compile annual living arrangement status for the HRS respondents.

There are four categories defined as one's living arrangement status in a HRS wave: (1) living alone; (2) living with other persons; (3) living with children; (4) living with spouse; (5) institutionalized; (6) deceased. These categories are determined from

four sources of information provided at each HRS wave: (1) the respondent's (R's) interview status, including interviewed and alive; nonresponse but alive, and deceased; (2) whether the respondent was institutionalized; (3) whether the respondent lived with a spouse or partner (SP/P); (4) whether the respondent lived with other household members or children (HHM/CHD).

The HRS cross-sectional Tracker File records respondents' interview status, interview dates, date of death, if appropriate, and interview type for identifying core and exit respondents. The biennial status indicates the living arrangement status that was resulted after prior living arrangement transitions. These respondents' biennial statuses are updated from the RAND variables `RwIWSTAT`, `RwNHMLIV`, `RwMSTAT` and `HwCPL` that track respondents' corresponding statuses longitudinally and correct inconsistency in the cross-sectional Tracker status. Since `RwNHMLIV` only has information for core respondents, institutionalization information for exit respondents was directly accessed from the HRS exit variables. The Tracker File only provides marital status indicators for 2004 and years after it. Although the between-wave status does not directly incorporate RAND's longitudinal variables, resulted between-wave transitions show only a few discrepancies to `RwMSTAT` and `HwCPL` that are possibly due to longitudinal correction by RAND. Neither the Tracker File nor the RAND HRS Data provides information for biennial statuses for household-members or children.

The same four components can be found in the biennial HRS for constructing one's living arrangement status between two HRS waves. The biennial HRS core/exit files provide (1) spouse or partner's in/out dates (e.g. when did you (R and SP/P) stop living together? when did you (new R or with new SP/P) begin to living together?); (2)

institutionalization admission/discharge records up to three times; (3) household member-child's in/out/died date. With the four components, one's between-wave living arrangement status can be constructed.

Methodology

Construction of Between-Wave Living Arrangement Status

The basic processes for constructing the between-wave living arrangement status is a backward procedure, meaning if there is a transition prior to the present interview, we then examine whether the respondent reaches the present status before or after a middle point between two biennial interviews as a pseudo interview date. If the transition date is before the pseudo date, we determine that this individual's between-wave status is the same as the status at the present wave; if the transition date is after the pseudo date, we determine that the individual's between-wave status is the same as the prior biennial wave. This basic rule is applied to all of the four components of living arrangements.

These odd year statuses are constructed using information from the next biennial core and exit interviews. For example, the 2002 respondents are respondents who (or whose proxy respondents) were given either a core or exit interview in 2002. For the 2002 core respondents, their self-reported dates are used to determined their living arrangement statuses at the pre-specified pseudo interview date in 2001; for the 2002 exit respondents, their date of death and self-reported dates are used to determine the same status by whether they have died and whom they lived with at the pseudo date in 2001.

The construction of between-wave living arrangement status begins with setting a midpoint between two HRS waves and checking whether there is a transition prior to the present status. Next, each of the four components described above is compiled, and their

missing data in self-reported time are screened. Last, the one's living arrangement status is then put together. Next, each of the four components described above is determined, such as the interview status and household member status, at the pseudo between-wave dates, and their missing data in transition dates are screened. Last, the household composition information is compiled as a single indicator of living arrangements for each individual, that in turn as file by year are merged to the master file and are streamlined as annual living arrangement status. The construction processes are discussed as follows.

The Midpoint of Two HRS waves as the Pseudo interview date

We have to decide a point in time at which a respondent's between-wave living arrangement status is assessed. Note that the respondents were not interviewed exactly every two years; instead, the time between two consecutive interviews may be more or fewer than 24 months. The majority of respondents are interviewed in both the present wave and the wave two years ago; there are some respondents who are only interviewed in the present wave but not in the wave before the present one. Thus, to approach one's annual living arrangement status, a pseudo interview date between two HRS interviews is set at the middle of two HRS interview dates or one year before the present biennial interview.

For respondents who were interviewed in two consecutive waves, the pseudo interview date is set to be a monthly date (a month of a particular year) at the exact middle point between the monthly dates of two biennial interviews. Almost all midpoint months are set in the year between two major interview years, for example, 2007 between the two HRS waves of 2006 and 2008. Few respondents' midpoints are set in early 2008 due to their corresponding 2008 interviews that are completed in early 2009.

For respondents who were only interviewed in the present wave, the pseudo interview date is set to be the month that is 12 month prior to the present biennial interview. Respondents who were not interviewed at the present wave may be (1) nonresponse or not interviewed in the earlier wave or (2) a new respondent who have never been interviewed and newly enters the study in the present wave. These respondents' midpoints are set regardless of when or whether they are (ever) interviewed.

The term "last wave" is used very specifically in this report. This term is used to refer to the interview wave in which the respondent or the household was last successfully interviewed, which can be the HRS wave precedes the present wave, or the wave that the respondent has last been interviewed. If the "last" interview is not the one before the present one, these respondents are seen as nonresponse in the corresponding wave and are followed up in the coming waves. For example, the last interview year for a respondent in 2008 may not be 2006; instead, this respondent was not interviewed in 2006 but was successfully interviewed in 2004. Thus, the last interview for the respondent in 2008 actually refers to the 2004 interview.

Constructing transition indicators between two biennial interviews

The general rule of backward construction is applied for all four components. However, each of the four components has its own way for determining the status at the pseudo date. Collectively, the information is compiled as a transition status indicator for each of the four components. The details are discussed in depth later by each of the components. Before turning to the issue of missing data in dates, we discuss some typical cases of missing data in transition indicators.

There are also missing data due to the HRS's programming errors or skip patterns (or branch point design). For example, in 2008, 150 new resident children or children-in-law were erroneously skipped the questions about their move-in dates according to the communication with the HRS's help desk. This issue has been fixed in 2010; the whole part was rewritten. Also in 2008, there are 40 respondents who were not coupled in the last interview but reported to be newly or re- married/partnered between waves but were not living with their spouse or partner at the time of interview. Due to a skip pattern, they were administered only with when they stopped living with their new spouse or partners but not when they started living with their new spouse or partners.

In 2012, the HHM's previous wave residency status contains substantial missing data in addition to new children or household members. According to the HRS's help desk, certain children or household members' data were not updated and left blank because this variable may potentially be dropped from publicly released in the future. The missing data for the HHM's previous wave residency cause a high proportion of residency transitions that cannot be determined at the midpoint, resulting in a correspondingly high proportion of missing residency status in 2012.

Missing data screening

Each of four living arrangement components could have missing data in reported dates of transition. For example, a respondent may report that he/she has stopped living with his/her spouse, but does not provide in what year and/or month they stopped living together. Because one's between-wave status comes from different sources of information, missing data can accumulate and affect whether we could determine one's between-wave living arrangement status.

A legitimate way to screen the missing data is to discount missing data in dates that do not possibly fall in the year of midpoint using available non-missing information. The missing data that cannot be discounted will determine whether if we can assign one's between-wave living arrangement status.

In practice, I first flag observations that are determined to have a transition but are not associated with a valid transition date, such as missing in the month and/or the year of transition. Because these observations come from the group that has been determined to experience a transition, these observations are essentially the missing data in each of the four components of living arrangements. However, due to partial information that may be still available and may be used to rule out the missingness for determining the pseudo date status, I further remove the flag and retain some of these observations and leave the rest as missing. Lastly, the observations that are still flagged are coded as missing in the specific components.

Note that the hierarchy of living arrangements may help to alleviate the missing data issue to some extent. For example, if a respondent is found to be institutionalized at the midpoint, his/her missing data in when stopping living with his/her spouse or partner becomes irrelevant. In these processes, there are missing data that could accumulate or cancel each other out due to the hierarchy of living arrangement status.

Missing dates after screening are not imputed and left as they are. Few institutionalized respondents who report their admission/discharge years in valid values but months by season. Their admission/discharge months were coded as the middle month in the reported season.

Living Arrangement Indicator at the Pseudo Between-wave Date

A respondent's between-wave status in living arrangement is constructed hierarchically from four components possibly with missing data. A single indicator of living arrangements is resulted in six waves of between-wave statuses. One's between-wave status is assessed accordingly by whether the respondent was alive, institutionalized, and living with spouse/partner or a household member/child. If none of the above was true, the respondent is assigned to be living alone. Specifically, if a respondent will be assigned as institutionalized between two waves if he/she was found to reside in an institution at the time regardless of whom he/she lived with.

Longitudinal Merge

The longitudinal merge of between-wave status begins with the preparation of an index file that is based on the cross-sectional Tracker file released by the HRS and supplemented by the longitudinal RAND HRS Data produced by the RAND Corporation. The cross-sectional interview status is identified by the Tracker's variable `xIWTYPE`, which represents whether (obtained or not) and what kind of interviews (core, exit, post-exit, and not in sample) are linked to the observation.

There are six between-wave statuses to be merged, including statues in 2001, 2003, 2005, 2007, 2009, and 2011. For each odds year, the exit file is appended to the core file in the corresponding year and undergone the between-wave living arrangement status construction and missing data screening. After the coding for the core and exit interviews and constructing the single indicator of living arrangements, the six resulted files are merged back to the index file, which becomes the master file of annual living arrangements status.

Streamline the Annual Living Arrangement Status

The respondents who are not in either core or exit interviews in the biennial wave would be left missing at the first with their between-wave status because no information from the biennial interviews is available. These respondents may be alive, dropped from the sample, or have died in an earlier wave, updated from the biennial status. The nonresponse status (alive or dropped from sample) reported in a biennial interview is carried backward to a missing between-wave status prior the biennial interview; the mortality status at a biennial interview is carried forward to the next missing between-wave status because the biennial status differentiates died at this wave or at a previous wave. After the carry forward or backward procedures, there are still a small number of respondents whose between-wave statuses were missing. The rest of missing between-wave status belongs to those died prior the present biennial wave. Their exit interview was not obtained. Their between-wave statuses are determined by comparing their date of death and the pseudo interview dates for nonresponse or mortality status at the pseudo date.

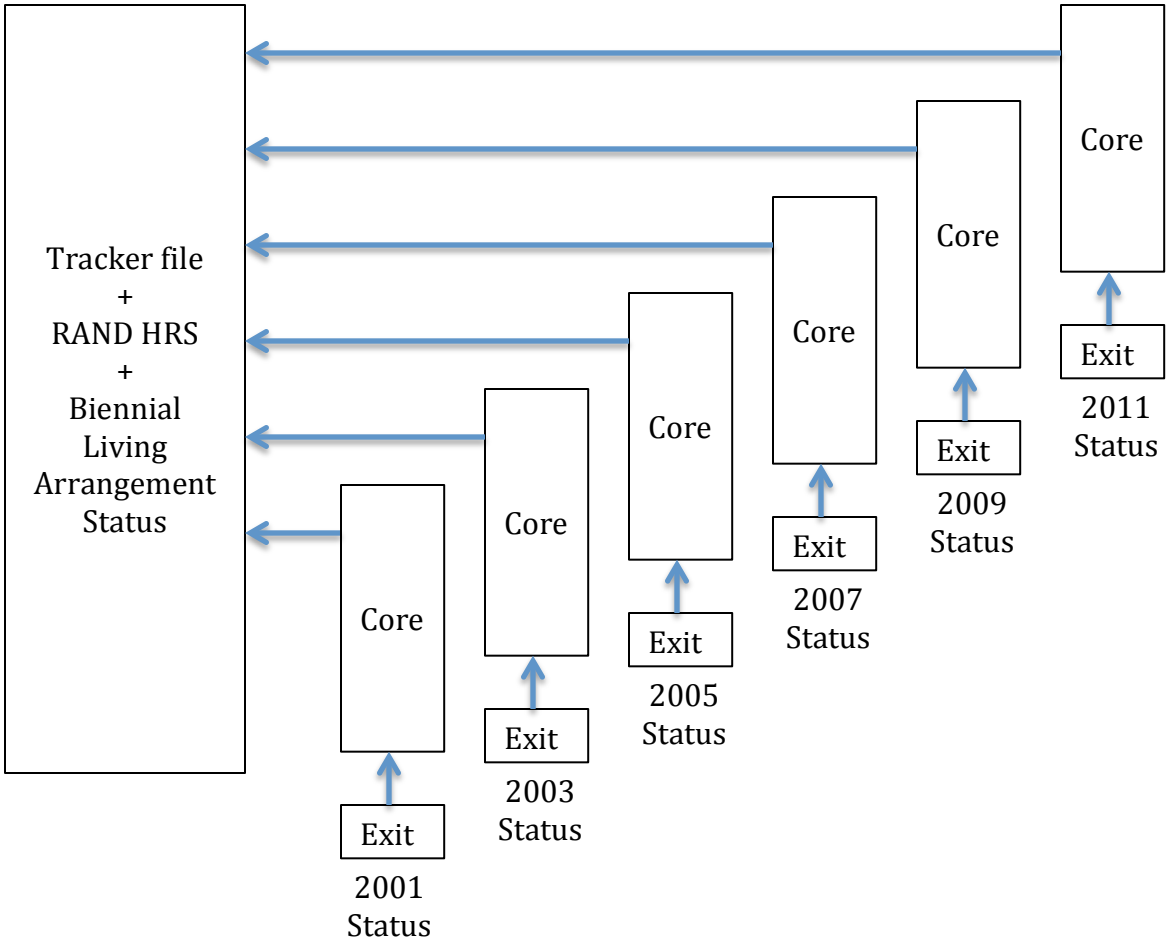

Figure A.1 Longitudinal Merge of Between-Wave Living Arrangement Statuses

Data

The master file is constructed using both the Tracker 2012 (Final Release, Version 1.0, March 2015) and RAND HRS data (Version N, September 2014). The data construction has been completed and updated by March 2015.

The core files that are used to constructed between-wave status are compiled directly from the RAND HRS Fat files, including:

1) HRS 1998 Fat, Final Version 1.0, February 2014
2) HRS 2000 Fat, Final Version 1.0, May 2011
3) HRS 2002 Fat, Final Version 1.0, May 2011
4) HRS 2004 Fat, Final Version 1.0, May 2011
5) HRS 2006 Fat, Final Version 1.0, May 2011
6) HRS 2008 Fat, Final Version 1.0, February 2014
7) HRS 2010 Fat, Final Version 4.0, June 2014
8) HRS 2012 Fat, Final Version 1.0, October 2014

The variables for household-members/children come from the preload household-member/child file in the HRS core data, including:

1) 1998 Core, Final, Version 2.3, November 2003
2) 2000 Core, Final, Version 1.0, April 2004
3) 2002 Core, Final, Version 2.0, July 2006
4) 2004 Core, Final, Version 1.0, September 2011
5) 2006 Core, Final, Version 3.0 December 2014
6) 2008 Core, Final, Version 3.0, December 2014
7) 2010 Core, Final, Version 5.0, December 2014
8) 2012 Core, Final, Version 1.0, Final V1.0, December 2014

Since the RAND Fat files do not contain information from exit interviews, all the information for the deceased respondents is compiled directly from the exit data, including:

1) 1998 Exit, Final Version 1.0, January 2005
2) 2000 Exit, Final Version 1.0, March 2005

3) 2002 Exit, Final, Version 1.0, December 2006
4) 2004 Exit, Final, Version 1.0, September 2011 [qn updated]
5) 2006 Exit, Final, Version 1.0, October 2008
6) 2008 Exit, Final, Version 1.0, November 2010
7) 2010 Exit, Final, Version 2.0, September 2012
8) 2012 Exit, Final, Version 1.0, March 2015

Next, the transition indicators of four living arrangement components are discussed accordingly.

Limitations

The first potential issue may emerge, as this living alone indicator is constructed using retrospective information provided at the current cross-section at the midpoint and not considering cross-wave consistency. Achieving the cross-wave consistency would require enormous efforts and would not avoid the inherited bias of retrospective data that respondents may not give a hundred percent correct answers for questions regarding earlier years. Thus, constructing between-wave indicators may be a compromise or an efficient way to exploit the data and to overcome its potential flaws.

The first issue may be justified, but the cross-section status for institutionalization may also reflect a limitation that institutionalization in later life may occur more frequently, whereas the cross-sectional interview may only capture those in a nursing home at the point of interview. An extension to this point is that I cannot distinguish long-term vs. short-term institutionalization, which could be a limitation for all the studies using survey data like the HRS. Only claim data can give the detail such as the length of stay in a nursing home or post-acute care facilities. Thus, from the view of data structure, the

between-wave status construction is the same as any panel data conducted at a cross-section and then being carried out or linked longitudinally.

The third limitation is the lack of family formation data or household member in/out dates before 2002. Since 2002, the HRS introduces a set of questions about the in/out/died dates of household members and children, based on which I construct whether a respondent live with anyone other than a spouse or partner. In other words, I can construct hhm-child's residency status in 2001 using the 2002 data, which make it possible to stretch the observation period annually from 2000 through 2012 and give 13 years of transitions. However, the 1999 status is not available because the 2000 HRS did not have the information, which may force me to give up the 1998 data for two potential annual transition points.

APPENDIX B

SEQUENCE ANALYSIS

This appendix contains three entries regarding the patterns of missing sequence data, the imputation method, and the documentation of clustering results.

Missing Sequence Data

Missing data in living arrangement sequences are caused by (1) inability to determine a between-wave status from available biennial data; (2) simple nonresponse at the biennial interview; (3) inability to determine a between-wave status because of nonresponse at the corresponding biennial interview; and (4) nonresponse at the biennial interview because of being dropped from the sample.

Simple nonresponse at a biennial interview can temporarily result in missing living arrangement data because contact will be attempted in later interviews. Individuals dropped from the study are often done so by request of interviewees, so that missing data are permanent. Note that attrition due to mortality is not considered a missing status in the study because mortality is defined as one of the living arrangement states.

A single missing value for between-wave status may result in missing status with gap length of one year. They are missing mainly because information from biennial interviews suggests a change in living arrangements was made prior to the later interview, but there is not a valid date of the change for determining the between-wave status. Note that gaps with one-year length are exclusively missing between-wave statuses.

Simple nonresponse at a biennial interview not only causes missing data in the biennial status but also fails to provide necessary information for constructing a between-

wave status. If a biennial status is missing, the preceding between-wave statuses will be missing as well. The two consecutive missing statuses become a gap with length of 2 years. More consecutive missing data on biennial states become gaps with length in greater even numbers (e.g. 4, 6, 8, and so on).

Non-response at the current wave may raise concerns about determining the between-wave status (year 1) following the current biennial wave (year 0) and prior to the subsequent valid interview wave (year 2). However, the design of the HRS questionnaires dictates that the questions about transitions and corresponding dates refer to the changes since the last valid interviews (year -2, -4, -6, or earlier). The nonresponse in the current wave is thus irrelevant because the next available interview would provide information regarding the changes in household composition since the last valid interview. Note that, the study only constructs the specific between-wave status between the nonresponse wave and the subsequent valid wave. Any remaining missing data in years between the last valid interview (year -2, -4, -6, or earlier) and the between-wave status (year 1) are left missing.

Nonresponse due to being dropped from the study sample results in terminal missing— sequence data missing stretched from the end of a sequence (See Halpin, 2013). Same as simple nonresponse at biennial interviews, this type of missing data constitutes a gap with expected missing between-wave status. The gap length of terminal missing is also in even numbers. There is no terminal gap with length of odd number, reflecting the fact that terminal missing always begins with a missing biennial interview at the end of the sequence.

Imputation for Missing Sequence Data

Sequence data present serious challenges for imputation (Halpin, 2012). First, high levels of collinearity among repeated observed statuses will bias the estimation if these statuses are directly used as separate variables for prediction. Second, consecutively correlated missing data exhibit a gap structure and cannot be seen as merely separated missing variables. Ignorance of the gap structure may result in unrealistic or even spurious imputations. Halpin (2012; 2013) proposes an imputation approach for sequence data by closing the gap from both ends. This approach attempts to maintain the longitudinal consistency of a sequence by considering the last and the next available living arrangement statuses of a gap. The "future" status that have been observed are treated the same as the "history" status prior to the gap. In other words, the imputation method is concerned with modeling their joint distribution instead of causal relationships.

Note that patterns of missing data in living arrangement sequences are also closely related to the approach that constructs the between-wave statuses. Missing between-wave status are exclusively linked to internal gaps with length of one year. The combination of nonresponse at biennial interview and the expectedly missing between-wave status prior to the biennial interview constitute a gap with length of two years. Moreover, consecutive missing biennial interviews result in gaps with length of greater even numbers (e.g. 4, 6, 8, and so on).

Some nonresponse status at biennial interview may coincide with two missing between-wave status prior and subsequent to it, constituting a gap with length of three years. Similarly, larger gaps with length of greater odd numbers (e.g. 5, 7, 9, and so on) may appear if there are consecutive missing biennial interviews with additional missing

between-wave statuses next to them. These gaps in odd number of years may appear when the attempt to construct between-wave statuses fails due to missing values in information determining the household composition as provided in the subsequent valid interview.

Lastly, terminal missing—missing data stretched from the end of a sequence are always in length of even years, reflecting the same combination of the missing biennial data and the preceding between-wave status that is expected to be missing. Overall, the combination of the missing biennial status and preceding between-wave status lead to a pattern that gaps of even years substantially outnumber gaps of odd years.

In Table B.1, assuming that the 1999 status is not missing, there are 8,298 respondents have a complete living arrangement sequence constituted by 15 annual observations over 14 years without a gap. About 20 percent of respondents have one gap episode, whereas about three percent of respondents have two or more gap episodes. Concerning the largest gap within a sequence, about 15 percent of sequences contain one or more gaps, of which the maximum gap length is up to three years. Eight percent of sequences have maximum gap length that is larger than three years.

After examining the data and feasible techniques, I decided to impute the gaps up to three missing statuses from the distribution of available sequence data. The three-year gap length is chosen because (1) these gaps are often related to a single missing biennial status within the gap, and (2) imputation for gaps more than three years may become less reliable, and (3) a lengthy gap may be related to more dramatic changes in living arrangements, which raises the concern about how to validate the imputed results.

Table B.1. Length of the Largest Gap within A Sequence and Number of Gap Episodes for the Study Sample Aged 65 and Over, Excluding the Missing 1999 Status

Length of Largest Gap	Number of Gap Episodes						Total
	0	1	2	3	4	5	
0	8,298	0	0	0	0	0	8,298 (77.1)
1	0	688	84	8	0	1	781 (7.3)
2	0	682	117	16	0	0	815 (7.6)
3	0	44	9	0	0	0	53 (0.5)
4 and larger	0	687	112	10	1	1	811 (7.5)
Total	8,298 (77.1)	2,101 (19.5)	322 (3.0)	34 (0.3)	1 (0.0)	2 (0.0)	10,758 (100.0)

Source: Author's calculation

I followed Halpin's core approach but impute the missing data using the three-period sequence data.[2] First, a cross-tabulation of nonmissing living arrangements of a middle year is calculated given the combinations of the last and the next available living arrangement statuses, from the entire study sample. This percentage distribution is retained for assigning missing statuses in the middle year for the same last and next available living arrangement statuses. Second, the imputed status is assigned at random based on the above distribution given the last and next states in place.

Since the target gap length for imputation is up to three years, there were three rounds of imputations (See Figure B.1). The imputation begins with the last element of the longest gap (the three-year gaps), switches to the first element of the next longest gap (the two-year gaps), and then imputes the single missing element of the one-year gaps. At each round of imputation, the distribution will be recalculated, taking into account of the newly imputed status.

[2] Halpin's automated multiple imputation approach has been attempted. Due to multiple sparse categories, the multinomial logit regression model—the predictive model that produces the estimated probabilities for missing status—failed to converge.

Figure B.1. Illustration of Imputation Process

Round	Three Year Gap	Two Year Gap	One Year Gap
0	■■■□□□■■■	■■■□□■■■■	■■■■□■■■■
1	■■■□□☒■■■	■■■□□■■■■	■■■■□■■■■
2	■■■☒□☑■■■	■■■☒□■■■■	■■■■□■■■■
3	■■■☑☒☑■■■	■■■☑☒■■■■	■■■■☒■■■■

Note: Revised from Halpin (2012); □ indicates a gap element; ☒ indicates a gap element to be imputed; ☑ indicates an imputed element.

As mentioned above, terminal missing is limited in gap length in even numbers. Thus, I impute terminal missing data in the last two years. Using information only from one end, imputed values are derived at random from the living arrangement distribution given the last available status. The first element of the two-year terminal gaps is imputed firstly; the second element is then imputed based on the distribution the last living arrangement statuses including the imputed first elements.

One may argue that imputing terminal missing from known statues in one end is prone to errors. The 460 respondents with terminal missing data of two years are almost exclusively nonresponse in the last interview wave in 2012. They stand for about 4.3 percent of 10,758 age-eligible respondents. They are not respondents who have not been interviewed in multiple waves. It is possible that imputation for terminal missing based on the last known status would fail to consider the statuses in even earlier years. Without sophisticated techniques, current studies often use the same approach of imputing terminal gaps and simply rely on known information from the past (Crimmins, Hayward, Hagedorn, Saito, & Brouard, 2009; Halpin 2012; 2013). The imputation should be suitable for the simple scenario of terminal missing of two years and, is unlikely to cause potential bias due to poor health at advanced ages. Imputed results are shown in Table B.2.

Table B.2. Imputed Statuses for Terminal Gaps in Two Years

	Gap year 1	Gap Year 2
Alone	25.9	26.5
Living with others	3.3	3.3
Living with children	11.1	12.0
Living with spouse	53.7	52.6
Institution	6.1	5.7
N	460	460

Source: Author's calculation

Imputed results of no or one transition may be suitable for evaluating the longitudinal consistency of the imputed results. Having no change suggests that the missing statuses are imputed to be the same as the prior and subsequent status of a gap. Having one transition implies the difference between the prior and subsequent statuses, and the transition that must be observed at either the midpoint or a point closer to either of the two interview dates of known status.

Table B.3 shows the imputed results. Overall, 3% of the imputed gaps are imputed to have two or more transitions, suggesting few multiple transitions and good longitudinal consistency. Among the one-year gaps, 76% of sequences were imputed to have no transition. The percentages of having no transition decrease disproportionately as the gap length increases.

Table B.3. Percentage Distribution of Imputed Results by Gap Length and Resulted Transition for the Study Sample Aged 65 and Over

Resulted Transition	One Year Gap			Two Year Gap	Three Year Gap	Total
	All One Year Gap	1999 Status	Other One Year Gap			
0	78.3	83.4	28.2	48.5	7.3	75.5
1	19.3	14.7	63.8	42.2	67.3	21.4
2	2.5	2.0	8.0	8.9	23.6	3.1
3	-	-	-	0.4	1.8	0.0
4	-	-	-	-	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0
(n)	(10,691)	(9,693)	(998)	(979)	(55)	(11,725)

Source: Author's calculation

Note that interpretation of imputed three-year gaps should be done cautiously because the number of cases is very small. Possibly due to less diverse living arrangement statuses in 1998, 83% of single year gaps in 1999 were imputed to be the same as the prior and the subsequent status. Similar patterns appear if we decompose the two- and three-year gaps by time since baseline. However, for other one-year gaps that are located farther from baseline are much less likely to have no imputed transition but more likely to have one imputed transition, suggesting the farther from baseline, the more likely a transition would occur.

Cluster analysis

The purpose of cluster analysis is to determine the natural groupings or clusters of observations that may exist in data (StataCorp, 2011c). As prior studies on sequence analysis have done, I use hierarchical cluster-analysis with Ward's linkage method to determine the number of clusters. The Stata hierarchical method creates sets of clusters iteratively that are hierarchically related and adopts the agglomerative approach. In the first iteration each observation is treated as a separate group, and then the two closest groups are combined into a single group. In the second iteration, the next two closest groups (including the combined group) are combined together. The process of combining the pair of closest groups continues in subsequent iterations until all observations are assigned to one group. A hierarchy of clusters is thus created, and stopping rules must be employed to evaluate the proper grouping of individual observations.

Stata's Cluster analysis has two stopping rules for determining the number of clusters, including the Calinski-Harabasz pseudo-F index and the Duda-Hart Je(2)/Je(1)

index and pseudo T-squared values (StataCorp, 2011c). Depending on the stopping rule, larger or smaller stopping rule values indicate the more distinct solution of clustering. Both large Calinsky-Harabasz index and Duba-Hart Je(2)/Je(1) index characterize distinct cluster solution. Only small Duba-Hart pseudo T-squared value characterizes distinct clustering. Cluster trees or dendrograms are also useful in examining the height of the vertical lines and the range of the (dis)similarity axis. In short, long vertical line in the cluster trees suggests distinct groupings. For unknown reasons, cluster trees for two subgroups cannot be drawn with error message “currently can't handle dendrogram reversals”, which should be graphing error and does not affect the clustering.

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