# Ageing and Cognitive Impairment: Modelling the Trajectories Using Dynamic Microsimulation Approach

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## Abstract:

This paper presents an application of dynamic microsimulation technique in modelling future scenarios of age-related disabilities and associated lifestyle risk factors, with a focus on cognitive impairment or probable dementia. The incidence of probable dementia was modelled on the basis of age, sex and education. The model tracked various age-cohorts, the youngest being aged 45-49 years at the beginning of the simulation. Future age-specific prevalence and incidence rates of probable dementia for the cohort aged 45-49 years are broadly in agreement with external cross-sectional estimates. Average expected years of life lived with dementia are also comparable to estimates based on life table method. The validated outcomes serve as a baseline against which results from further policy analysis from an enhanced model could be compared.

## Acknowledgements

The data on which this research is based were drawn from several Australian longitudinal studies including: the Australian Longitudinal Study of Ageing (ALSA), the Australian Longitudinal Study of Women's Health (ALSWH), the Australian Diabetes, Obesity and Lifestyle Study (AusDiab), the Blue Mountain Eye Study (BMES), the Canberra Longitudinal Study of Ageing (CLS), the Household, Income and Labour Dynamics in Australia study (HILDA), the Melbourne Longitudinal Studies on Healthy Ageing (MELSHA), the Personality And Total Health Through Life Study (PATH), and the Sydney Older Persons Study (SOPS). These studies were pooled and harmonized for the Dynamic Analyses to Optimise Ageing (DYNOPTA) project. DYNOPTA was funded by an NHMRC grant (# 410215). All studies would like to thank the participants for volunteering their time to be involved in the respective studies. Details of all studies contributing data to DYNOPTA, including individual study leaders and funding sources, are available on the DYNOPTA website (http://dynopta.anu.edu.au). The findings and views reported in this paper are those of the author(s) and not those of the original studies or their respective funding agencies. The authors would like to thank Linc Thurecht for his comments and suggestions on an earlier draft of this paper.

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# Introduction

This paper uses dynamic microsimualtion to project prevalence and incidence of probable dementia and number of years of remaining life lived with and without this condition in selected age-cohorts of Australian adult males and females. Dementia refers to a collection of symptoms resulting from the gradual deterioration in cognitive functions that are in excess of what might be expected from normal ageing. Dementia has become a global health challenge and its overall prevalence is likely to increase in the coming decades in keeping with the longer survival and population ageing (Ferri 2009).

Dementia is a major cause of disability at older ages. Its prevalence increases sharply with age among those aged in their late 60s. Thus it might be expected that dementia will affect more people and that more years of life may be spent with this disability as people live longer in an ageing society. However, this is a simplistic view. It is not evident whether the duration with dementia is compressed or expanded as newer birth-cohorts live longer, nor by how much a delayed incidence compresses the duration of dementia. In the health literature, this question has been discussed under the framework of compression and expansion of morbidity.

The expansion of morbidity hypothesis suggests that technical advances extends survival but that subsequent declining mortality contributes to a longer duration of ill health (Gruenberg 1977). In contrast, Fries (1980), proposed a compression of morbidity hypothesis, arguing that duration of disability can be compressed towards the end of life if the incidence of disability is postponed. Robine and Michel (2004) proposed that these hypotheses are not exclusive and that different populations may have different experiences with regard to changes in disability levels at older ages depending on their stage of ageing. The aim of this paper is thus grounded in the broader question of whether morbidity or disability increases or decreases as people live for longer.

We focus in this paper on dementia. Dementia is a major cause of disability among older Australians. Based on prevalence estimates from various countries (Jorm et al. 1987; Lobo et al. 2000; Anstey et al. 2010a) it can be inferred that dementia prevalence rates tend to double for every five years after 65 years of age, reaching around 50 per cent in those aged 90 years or over (Nepal et al. 2008a). The rapidly growing prevalence of dementia at older ages suggests that the length of life spent with dementia is likely to significantly influence the length of time older people are likely to live with disability in general. Previous population level estimates for Australia show that men and women in their late 60s or early 70s would expect to live, on average, between one and two years of remaining life with dementia (Ritchie et al. 1994; Nepal et al. 2008a). These estimates were derived by using aggregate data on age-specific dementia prevalence rates and mortality and by applying the Sullivan Method, a life table approach for deriving a single index of morbidity (Sullivan 1971). While the estimates from these studies provide some useful indicators, the approach produces only limited aggregate indicators of life expectancy with dementia. Ladikta and Wolf (1998) have demonstrated that more advanced approaches, such as microsimulation modelling, provide more efficient methods to derive accurate indicators of health-adjusted life expectancy.

This paper broadens methodological knowledge in this field by developing a dynamic microsimulation method to project the prevalence, incidence and number of years lived with and without probable dementia among men and women of various age-cohorts. The advantage of microsimulation modelling is that it provides an opportunity to derive more reliable estimates than using aggregate prevalence and mortality data. This paper proceeds with a description of the microsimulation model in the next section. It then presents selected results. Finally, the capabilities, usefulness and areas for improvement of this model are discussed.

# Method

The projections of prevalence, incidence and years lived with and without probable dementia (also referred to as dementia in this paper) were derived by using a dynamic microsimulation model called DynoptaSim. This model was built as part of the DYNOPTA (Dynamic Analyses to Optimize Ageing) Project (Anstey et al. 2010b). The project aimed, *inter alia*, to establish a demographic modelling infrastructure to simulate the health outcomes of Australia's older population and to examine the impacts of possible social and medical interventions to compress morbidity and optimise ageing in Australia into the future. The DynoptaSim model focusses on four conditions that contribute to the burden of disease and quality of life in the aged: cognitive impairment (dementia); sensory impairment; mobility impairment; and depression. This paper examines cognitive impairment or more particularly dementia representing significant cognitive impairment. Probable dementia is defined as having a Mini-Mental Examination Score of less than 24 following Anstey et al (Anstey et al. 2010a).

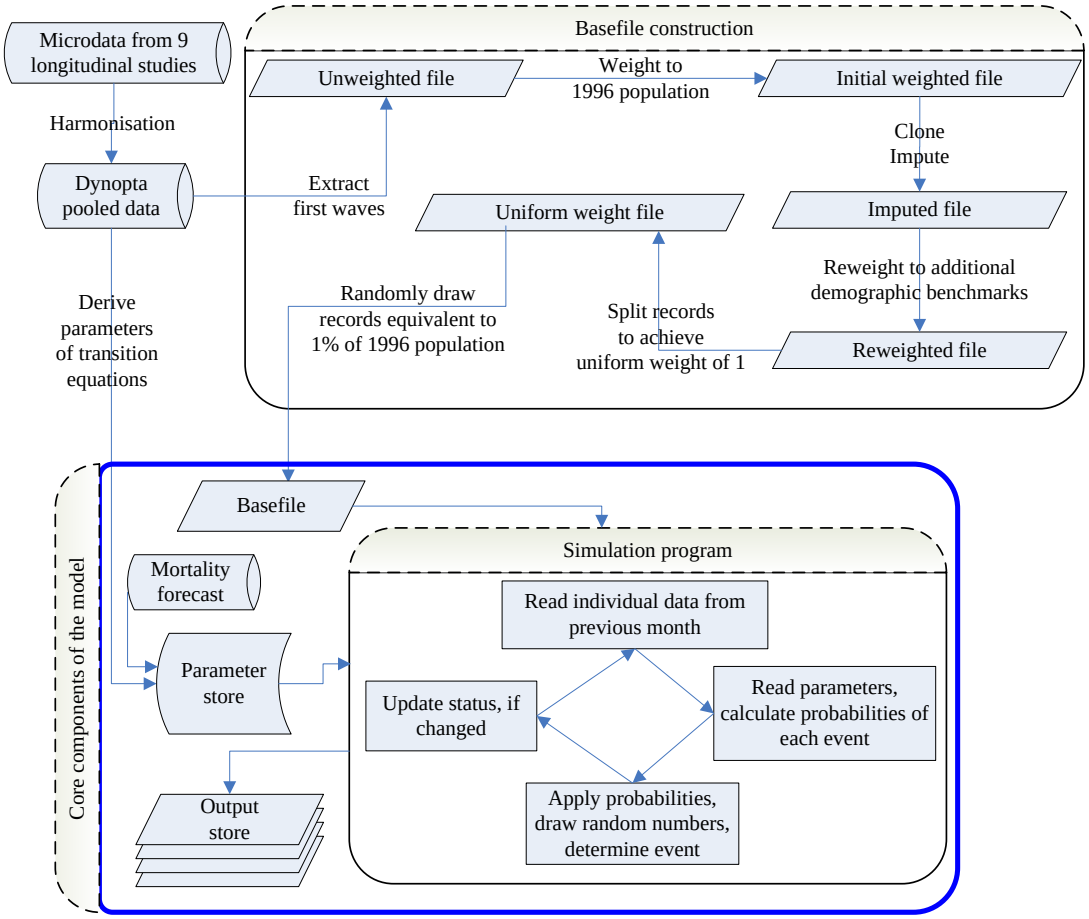
**DynoptaSim: the basic model**

The model consists of a basefile, a parameter store, a simulation program and an output store (Figure 1). The basefile is a unit record file of persons aged 45 years and over prepared from the first waves of nine Australian longitudinal studies of ageing combined in the DYNOPTA pooled dataset (Anstey et al. 2010b) and comprises the starting population of individuals in the model. The basefile was weighted to represent the 1996 Australian population in this age segment. The parameter store contains equations (coefficients) needed for deriving transition probabilities. The model adopts a discrete time approach, implementing a monthly interval to model change in states. It assumes that the transition from one state to another depends on the current state and is independent of past or future states.

In this model, the individuals simulated are not related to one another as couples or household members. A few major household characteristics such as partnership status and living arrangement (institutionalisation) are attached to each record as unique variables. Immigration and emigration are not processed. International migration in Australian is very low after 45 years of age. For example, data on settler arrivals and permanent departures for the 2010-11 financial year showed that there were only a total of 3,287 settler immigrants to Australia aged 65 years and over and only 3,604 permanent emigrants (www.immi.gov.au/media/statistics/statistical-info/oad/). Therefore the extra complexity necessary to incorporate migration was considered unwarranted. Death is the only exit from the model. Thus the model tracks only one segment of the population *viz.* the cohort aged 45 years and over which eventually dies out. Cross-sectional estimates can only be produced for a limited time frame, not

for the entire simulation period. In this way, the model differs from other population dynamic microsimulation models, such as the Australian Population and Policy Simulation Model (Harding et al. 2011), which deal with the entire population and produce cross-sectional projections over the entire simulation period.

**Figure 1 Design of DynoptaSim**




For the purpose of this paper, we used a version of DynoptaSim in which the change in dementia status for each individual is predicted on the basis of three characteristics, namely, age, sex and schooling; mortality is disaggregated by dementia status; and survival is set at 110 years of age. It is assumed that dementia is irreversible – once an individual is assigned a state of dementia in the model then they remain in this state until they either die or the simulation period ends.

**Transition probabilities**

The probability of transition from a healthy state to dementia, $p$, between the first and the second observations was estimated as a function of age, sex and schooling. These equations were derived from the first and second waves of the DYNOPTA pooled dataset. Survival was modeled using smoothed observed mortality rates to 2007 and forecast mortality rates for 2008 to 2062 based on smoothed historic mortality rates for 1968 to 2007 using coherent stochastic forecasting methods (Hyndman et al. 2011).

The equation predicting probable dementia can be expressed as:

$\ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1$ Age $+\beta_2$ Female + $+\beta_3$ Left school at age 15 years and over

where, $\beta_0$ is the intercept, and $\beta_i$'s are coefficients for covariates i=1 to 3.

Since the equation was based on two successive waves conducted *m* months apart, the probabilities were adjusted to obtain a monthly transition probabilities as follows:

monthly probability, p = $(1+P)^{\frac{1}{m}} - 1$

Mortality was disaggregated by dementia status. Mortality differentials for people with and without dementia were obtained by applying the probability ratios that were estimated by using age-specific total mortality rates for 1996 (Human Mortality Database), relative risks of mortality with dementia (Helmer et al. 2001), and age-specific probable dementia prevalence proportions (Anstey et al. 2010a).

Mortality rates for exposed individuals (i.e. those with dementia), $m_a^e$, in a given 5-year age group, $a$, were obtained by:

$m_a^e = R_a^{et}\, m_a^t$

Where,
$R_a^{et}$ is the relative risk of mortality for the exposed individuals.
$m_{a,s}^t$ is the total mortality rate.

Mortality rates of unexposed individuals (i.e. those without dementia) were obtained by:

$m_a^u = R_a^{ut}\, m_a^t$

where, $R_a^{ut}$ is the relative risk of mortality for the unexposed group.

$R_a^{ut}$ was derived from total mortality at age $a$, age specific prevalence of probable dementia ($f_a^e$) and $R_a^{et}$:

$R_a^{ut} = \frac{m_{a,s}^t - f_a^e R_a^{et}}{1-f_a^e}$

Data on relative risk of mortality with dementia was obtained from a French community-based cohort study (Helmer et al. 2001). In that study, relative risk of deaths with dementia was estimated to be 1.8 compared with the total population. It was estimated to be 1.59 for individuals aged 75 years and older and 1.37 for 85 years and older. These data were then used to derive the relative risk of dying for people without dementia. These relative risk data are comparable to that previously used by the Australian Institute of Health and Welfare (AIHW) (relative risk of 1.8 for ages up to 75 and 1.6 for ages 75 and over) to estimate incidence and duration of dementia in Australia (Mathers et al. 1999) and provide a further disaggregation across ages.

Prevalence proportions needed for this calculation were obtained from a recent Australian population based analysis (Anstey et al. 2010a).

Once age-specific mortality rates for exposed or those with dementia ($m_a^e$) and unexposed or those without dementia ($m_a^u$) were calculated, they were transformed into probabilities of dying ($q_a^e$ and $q_a^e$ respectively) using the equations:

$q_a^e = 2 \times 5 \times m_a^e / (2 + 5m_a^e)$ and $q_a^u = 2 \times 5 \times m_a^u / (2 + 5m_a^u)$

The probability ratios for those with dementia ($h_a^{et}$) and without dementia ($h_a^{ut}$) were then obtained as:
$h_a^{et} = q_a^e / q_a^t$ and $h_a^{ut} = q_a^u / q_a^t$

The ratios for those with dementia ($h_a^{et}$) and for those without dementia ($h_a^{ut}$) were assumed to hold constant into the future.

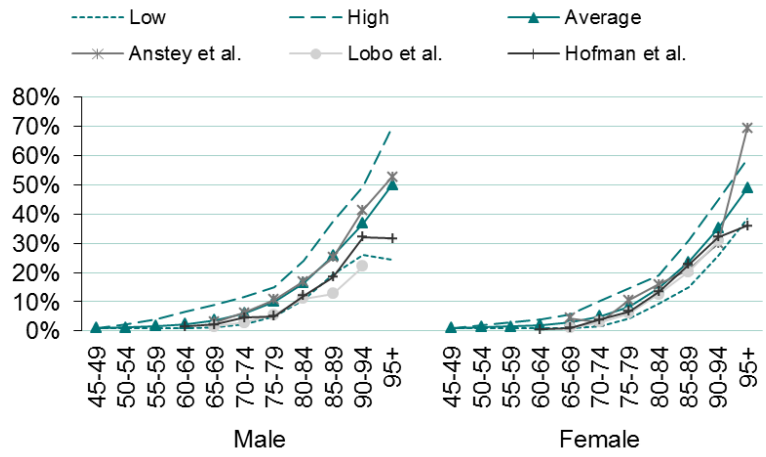
The maximum survival limit set in the simulations for a surviving person to reach was 110 years of age. Ten different simulations of 45,399 individuals aged 45 years and over at the beginning of the simulation were run. Each of the simulations used a different set of random numbers. This produced variation in the prevalence rates across the simulations, providing an indication of the uncertainty in the estimates. The starting population of 45,399 records represented one per cent of the Australian population in this age segment in 1996. The modelling was run over a 65 year simulation period, allowing all surviving persons to reach 110 years of age.

# Results

The simulation prevalence of probable dementia for the cohort aged 45-49 at the beginning are shown in Figure 2. The Figure also shows selected external cross-sectional estimates. The simulated results include the averages as well as the lowest and the highest values across the 10 simulations by 5-year-age groups for the cohort aged 45-49 at the beginning of the simulations and were tracked until death. Age-specific prevalence of the cohort aged 45-49 years at the beginning is comparable to the external cross-sectional estimates synthesised from population-based surveys of Australian adults in the 1990s and early 2000s (Anstey et al. 2010a) and those from meta-analytical studies of international data (Hofman et al. 1991; Lobo et al. 2000).

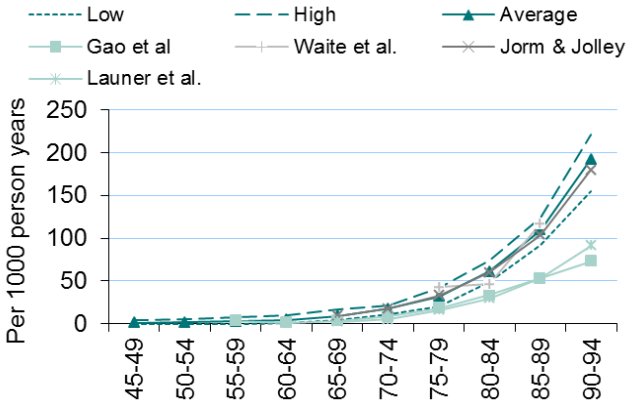
The simulated incidence rates of the cohort aged 45-49 at the beginning are also comparable to the meta-analytical estimates from Jorm and Jolley (1998) and to estimates of mild or more severe dementia reported by Waite et al. (2001) in the Sydney Older Person Study (Figure 3). These comparators are presented to illustrate the validity of the simulated results. They capture the wide variations observed in the measurement of cognitive impairment in the international literature (Ward et al. 2012).

**Figure 2 Prevalence of dementia**




Note: Low, high and average refer to lowest, highest and average values across 10 simulations for the cohort aged 45-49 at the beginning and tracked until death.
Sources of external estimates: (Hofman et al. 1991; Lobo et al. 2000; Anstey et al. 2010a).

**Figure 3 Incidence of dementia per 1000 person years**




Note: Low, high and average refer to lowest, highest and average values across 10 simulations.
Sources of external estimates: (Gao et al. 1998; Jorm and Jolley 1998; Launer et al. 1999; Waite et al. 2001).

Table 1 provides the findings for various indicators for selected age-cohorts. As Table 1 shows mean age at which dementia incidence occurs is in the mid-80s but there is a considerable variation between the low and high estimates across the 10 simulations. The cohorts in their late 60s or early 70s at the beginning of the simulation were expected to spend around 2 years of their remaining life with dementia. For example, individuals aged 70-74 years in 1996 were expected to live on average for another 14 years, but 1.8 (1.5−2.2) years of this would be spent with dementia. These estimates are comparable to previous population level estimates of life expectancy with dementia for Australia's older population (Ritchie et al. 1994; Nepal et al. 2008a).

**Table 1 Selected population level indicators on average years with and without dementia for selected cohorts**

| | Cohorts: birth years (age at baseline 1996) | | | | | |
|---|---|---|---|---|---|---|
| **Indicators** | *1922-26 (70-74)* | *1927-31 (65-69)* | *1932-36 (60-64)* | *1937-41 (55-59)* | *1942-46 (50-54)* | *1947-51 (45-49)* |
| Mean age at baseline | 71.9 | 67.1 | 61.9 | 56.9 | 51.8 | 47.1 |
| 1996 life expectancy estimates | 14.4 | 18.2 | 22.2 | 26.5 | 31.0 | 35.6 |
| Simulated mean person years lived* | 14.2 (12.8, 15.7) | 18.4 (17.6, 19.7) | 23.8 (21.4, 25.1) | 29.7 (28.3, 32.2) | 33.6 (30.1, 36.2) | 37.2 (35.2, 40.2) |
| Mean age at incidence of probable dementia* | 84.8 (84.4, 85.9) | 84.6 (81.3, 87.2) | 83.6 (79.5, 86.1) | 83.5 (81.3, 87.6) | 84.9 (81.7, 88.3) | 84.0 (81.4, 86.9) |
| Mean years lived with probable dementia* | 1.8 (1.5, 2.2) | 1.9 (1.5, 2.8) | 2.5 (1.4, 3.9) | 2.8 (1.6, 3.4) | 2.4 (1.6, 3.5) | 3.3 (2.0, 4.7) |
| Mean years lived without probable dementia* | 12.4 (11.3, 13.6) | 16.5(15, 18) | 21.3 (19.7, 22.4) | 26.8 (25.7, 29.2) | 31.2 (27.9, 33.8) | 40.5 (37.9, 43) |

Note: *Averages of 10 simulations; figures in parentheses are lowest and highest values across 10 simulations. Those identified with probable dementia at baseline were excluded in this analysis.
Source: 1996 life expectancy for both sexes taken from Human Mortality Database.

Total person years lived are likely to be higher for younger cohorts because the simulation uses mortality forecasts instead of keeping mortality rates constant at the baseline level. For example, the cohort of people who were aged 45-49 years in 1996 are expected to live a further 37.2 years on average according to the simulation, which is almost 2 years longer than the 1996 life expectancy estimate of 35.6 years for this group of individuals (Table 1).

Figure 4 shows the remaining life with and without dementia and the proportion of life with dementia for various cohorts at ages 75 and 80 years. While younger cohorts are expected to live longer overall in comparison with older cohorts, because age at dementia onset remains relatively constant across the cohorts, they are also expected to live longer with dementia - nearly doubling from 1.8 to 3.3 years (Table 1). The relative length of time spent with dementia will be longer for younger than older cohorts. This suggests that should the probabilities of transition to dementia remain the same, the duration of life with dementia will expand for the younger cohorts who are living longer on average.

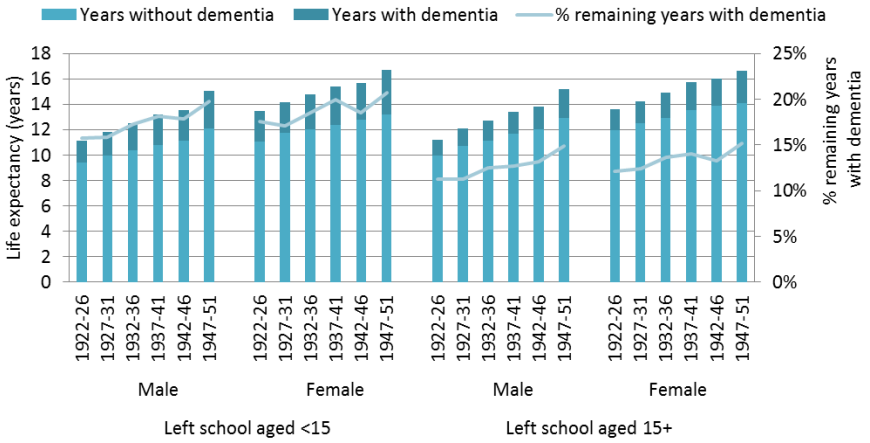
The impact of education on average years lived with and without probable dementia and percentage of remaining life lived with probable dementia by healthy males and females when they reached 65, 70, 75 and 80 years of age was also investigated (Table 2). These results are for the cohort of people who were aged 45-49 years at the start of the simulation.

The simulation results show that while total remaining life is longer for females, they would spend slightly more time with dementia than males. Those who left school before the age of 15 years are not only expected to die sooner but also spend more of their remaining life with dementia compared to those who left school at or over 15 years of age. In other words, people who spent a longer time at high school are

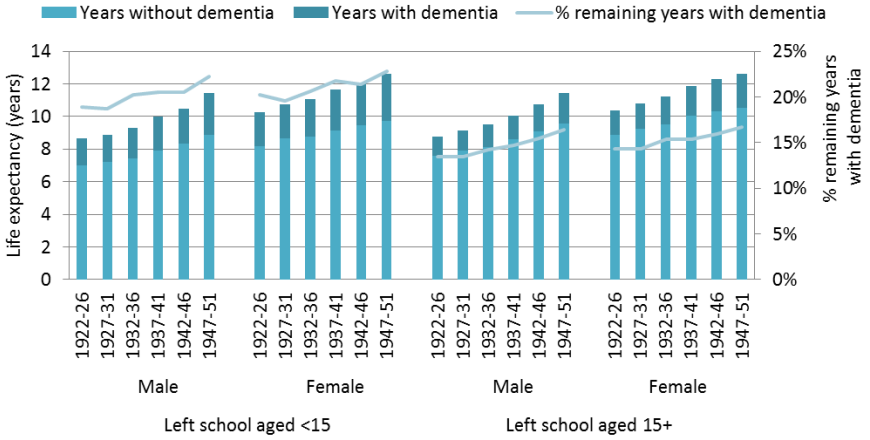
expected to enjoy longer life overall as well as longer time free of dementia in comparison to their early school leaving peers.

**Figure 4 Mean years of remaining life with and without dementia and percentage of remaining years with dementia by sex, schooling and age, various cohorts, a) at age 75 years, b) at age 80 years**

a) At age 75 years




b) At age 80 years




Note: Those identified with probable dementia prior to (a) 75 and (b) 80 years were excluded from the analysis.

Table 2 also shows that the longer individuals can stay dementia free the shorter the time they are then likely to spend with dementia. This is most noticeable for those who left school before 15 years of age, with a similar reduction in years lived with dementia being observed for both males and females. For example, if male early school leavers are dementia free at 80 years of age then they would only expect to spend 2.5 years with dementia over their remaining life but at 65 years of age they can expect to spend on average 3.8 years with dementia. For those who left school at 15 years of age or later, the duration of time with dementia preceding death reduced to 0.8 years and 0.9 years for males and females respectively, if their healthy years of life extended from 65 to 80 years. These results suggest that if people within a cohort

were to stay healthy for a longer period into their older age, the duration of their remaining life with dementia would be compressed.

**Table 2 Mean years of remaining life with and without dementia by sex, schooling and age, cohort aged 45-49 years at the start of the simulation**

| | | | With dementia | | | Without dementia | | | % remaining years with dementia |
|---|---|---|---|---|---|---|---|---|---|
| **Sex** | **Age left school** | **Age*** | **Low** | **High** | **Average** | **Low** | **High** | **Average** | **Average** |
| Male | <15 years | 65 | 2.4 | 5.7 | 3.8 | 17.5 | 21.0 | 19.2 | 16.5% |
| | | 70 | 2.5 | 5.1 | 3.4 | 13.7 | 17.1 | 15.5 | 18.0% |
| | | 75 | 2.2 | 4.3 | 3.0 | 10.6 | 13.2 | 12.1 | 19.9% |
| | | 80 | 1.8 | 4.0 | 2.5 | 7.4 | 9.9 | 8.9 | 21.9% |
| | 15+ years | 65 | 1.8 | 4.5 | 2.7 | 18.5 | 22.3 | 20.3 | 11.7% |
| | | 70 | 1.6 | 4.0 | 2.5 | 14.8 | 18.4 | 16.4 | 13.2% |
| | | 75 | 1.4 | 3.3 | 2.3 | 11.3 | 15.0 | 12.9 | 15.1% |
| | | 80 | 1.2 | 2.8 | 1.9 | 8.3 | 11.4 | 9.6 | 16.5% |
| Female | <15 years | 65 | 3.2 | 5.2 | 4.3 | 19.6 | 22.8 | 21.1 | 16.9% |
| | | 70 | 2.8 | 4.8 | 4.0 | 15.2 | 18.3 | 16.9 | 19.1% |
| | | 75 | 2.5 | 4.1 | 3.5 | 11.8 | 13.9 | 13.2 | 21.0% |
| | | 80 | 2.1 | 3.2 | 2.9 | 8.7 | 10.4 | 9.7 | 23.0% |
| | 15+ years | 65 | 2.0 | 3.6 | 3.0 | 20.9 | 24.0 | 22.4 | 11.8% |
| | | 70 | 2.0 | 3.2 | 2.8 | 17.1 | 19.3 | 18.1 | 13.4% |
| | | 75 | 1.7 | 3.1 | 2.5 | 13.0 | 15.0 | 14.1 | 15.1% |
| | | 80 | 1.4 | 2.4 | 2.1 | 9.6 | 11.3 | 10.5 | 16.7% |

Note: Low, high and average refer to lowest, highest and average values across 10 simulations.
*Those identified with probable dementia prior to this age were excluded from the analysis.

# Discussion

The DynoptaSim microsimulation model described in this paper provides a modelling infrastructure to explore future "what if" scenarios of the dementia epidemic in Australia. The future age-specific prevalence and incidence rates of probable dementia for the cohort of Australians who were 45-49 years old in 1996, i.e. at the beginning of the simulation, are broadly in agreement with external cross-sectional estimates. The outcomes will serve as a baseline against which results from policy intervention scenarios can be compared. In addition, the prevalence and incidence estimates obtained from this model are expected to provide a consistent set of data for the purpose of modelling the disease burden and economic implications of dementia in Australia.

The results suggest that persons in their late 60s, when the incidence of dementia starts to become more common, can expect to live about 2 years of their remaining life with dementia. Life expectancy with dementia obtained from the microsimulation modelling are comparable to those reported in previous Australian studies which used

prevalence-based methods (Ritchie et al. 1994; Nepal et al. 2008a). However, the present study provides an opportunity to examine variations across educational groups and birth cohorts. The modelling shows that individuals who left school at age 15 years and over not only had increased life expectancy but also longer dementia-free survival compared to those who were early-school leavers. This finding provides a potential policy lesson that enhancing educational outcomes in Australia's current younger generations may help minimise the future impacts of dementia.

The longer people remain healthy i.e. dementia free, the shorter the remaining life they will spend with dementia before they die. For a cohort tracked in this simulation, approximately between a half to one year was saved from the average years lived with dementia if the dementia-free period of the cohort was extended by 10 years from 70 years to 80 years of age. In other words, the duration of life with dementia would compress if the healthy years are extended longer into old age, that is, if the incidence of dementia is delayed. However, when multiple cohorts are compared, the simulation indicated that it was the younger cohorts who would experience a longer relative period of their lives with dementia than the older cohorts who had a shorter overall life expectancy. This suggests that given that the cohorts are exposed to the same set of factors predicting dementia occurrence, younger cohorts of older people who experience lower mortality would expect an expansion of dementia related morbidity.

A few past studies have examined this question in Australia. Looking at data from 1988 and 1998 surveys, Heathcote et al. (2003) estimated that all of the increase in life expectancy for males and two-thirds or more of the increase for females was spent in disability. Recently, the Australian Institute of Health and Welfare (AIHW 2006) argued that there was no evidence of compression of disability in the Australian population between 1988 and 2003 as the gain in life expectancy was accompanied by an increased share of life lived with disability, especially for older Australians. The AIHW study showed that 67 per cent of gains in life expectancy of men at age 65 years (1.5 years over that period) were years with disability (1 year) and, for women over 90 per cent of their gains in life expectancy at age 65 years (1.2 years) were years with disability (1.1 years). AIHW added that the growth in the relative amount of life with disability was related mainly to severe disability. These studies used cross-sectional data and focused on overall disability and its severity levels.

This study contributes to the growing application of microsimulation in the investigation of future health trajectories in ageing societies. In an earlier application of microsimulation modelling to derive indicators of life expectancy, Ladtika and Wolf (1998) estimated active life expectancy using transitions between multiple functional states. An another study used the Canadian LifePaths microsimulation model, an overlapping cohort model, to project disability in the Canadian elderly population and to calculate disability free life expectancy (Légaré and Décarie 2011). Unfortunately, the input data limited the present study to focus only on the transition from a non-demented to a demented state. Also, unlike LifePaths, the DynoptaSim model does not capture the total adult population ageing over time, although it does closely approximate the population aged 45 years and over, Thus, population level cross-sectional estimates are most reliable over the shorter term. Nevertheless, the ability of the model to compare within and between cohort outcomes in life expectancy with and without dementia provides additional and useful information to advance the discussion about the compression and expansion of morbidity.

While the results are comparable to previous studies and provide some useful insights for carers, service providers and policy makers, there is scope to further advance this modelling. First, the model can be improved to conduct policy 'experiments', or "what if" scenarios, to evaluate the potential impact of increased rates of school completion into the future. Second, in addition to education, a number of social, behavioural and biomedical factors have been found to influence incidence of dementia (e.g. Kivipelto et al. 2006; Anstey et al. 2007; Anstey et al. 2008). The approach presented here for predicting probable dementia only relies on age, sex and schooling. Inclusion of additional behavioural predictors in the model provides an opportunity to both independently and jointly investigate the impact of behavioural change on the incidence and prevalence of dementia. Third, Duration lived with dementia following its incidence was not directly included in the equations estimating the probability of dying with dementia, neither was the degree of severity of dementia owing to the lack of such differentiation in the model. When appropriate data become available, the mortality estimates can be improved. Fourth, the lack of modelling infrastructure to assess potential economic impacts of dementia in the ageing population of Australia has remained an important policy gap (Nepal et al. 2008b). The DynoptaSim model can be enhanced to conduct economic modelling of this type in two ways: by incorporating economic variables within the model, or by developing a separate model that can link the aggregate epidemiological outputs from DynoptaSim to exogenous financial data. Finally, only 10 simulations (repetition) were run owing to practical limitations of computing capacity. Ideally, a much large number of simulations, for example, 1,000 could be considered desirable to assess stochastic variations arising from the randomness. However, the ranges between the high and the low values across the 10 simulations were comparable to the range of confidence intervals around dementia prevalence estimates from cross-sectional studies.

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