Reducing loneliness to prevent depression in older adults in Australia: A modelled cost-effectiveness analysis

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ABSTRACT

Purpose: The aim of the study was to evaluate the cost-effectiveness of the Friendship Enrichment Programme (FEP) and a volunteer-led internet and computer training (VICT) intervention to reduce loneliness in older adults and, in turn, prevent depression.

Method: A population-based Markov model was developed to estimate the cost per quality-adjusted life year (QALY) gained and the return on investment (ROI) generated by investing in the interventions from a partial societal perspective. The model consisted of three health states (lonely, not lonely and dead). Costs, QALYs, and the subsequent impacts on depression associated with different health states were modelled. Both interventions were compared to a 'no intervention' scenario over a 5-year time horizon. Probabilitistic and deterministic sensitivity analyses were undertaken for both interventions.

Results: The incremental cost-effectiveness ratio was dominant across both interventions, indicating that they were less costly and more effective when compared to the comparator. Results remained robust in the deterministic sensitivity analyses. However, probabilistic sensitivity analyses indicated high uncertainty, with only 55% and 68% of uncertainty iterations lying below the A$50,000 per QALY gained willingness-to-pay threshold for FEP and VICT, respectively. Both interventions generated cost savings that were greater than intervention costs, with a ROI of 2.87 for the FEP and 2.14 for the VICT intervention after 5 years.

Conclusion: While FEP and VICT were found to be cost saving with positive returns on investment, the current evidence on intervention effectiveness is limited and needs to be strengthened before routine rollout can be recommended.

1. Introduction

The prevention of mental health disorders and the promotion of good mental health are key factors associated with healthy ageing. Nevertheless, an increasing number of older adults experience poor mental health, which is often affected by illness, the loss of independence, bereavement, financial stress, and changing living arrangements (Australian Institute of Health and Welfare, 2015). Depression among older people is a particularly significant public health issue, with 8.2% of community-dwelling older adults (Pirkis et al., 2009) and 52% of older adults in residential aged care experiencing depressive symptoms (Australian Institute of Health and Welfare, 2013).

A growing body of literature indicates that loneliness is an important risk factor for developing depression (Erzen & Cikrikci, 2018; Ge et al.,

2017; Courtin & Knapp, 2017; Cacioppo et al., 2010, 2006). Loneliness is defined as the discrepancy between a person's desired and actual social relationships (Masi et al., 2011). Loneliness impacts all age groups but particularly young adults (<25 years) and older adults (>65 years) (Lim et al., 2020). In Australia, the prevalence of loneliness is estimated to be around 17%, with the highest prevalence observed for people aged 75 years and over (19%) (Relationships Australia, 2018). These rates have remained relatively stable in recent estimates (Kung et al., 2021). Previous evidence has also indicated gender differences in age trends in loneliness, with increasing loneliness from age 40 to 80 for women, compared with a u-shaped curve for mean, with highest levels of loneliness at age 40 and 80 and lower levels in between (von Soest et al., 2020). Older adults are particularly prone to feeling lonely due to the death of partners and friends, retiring from work, deterioration in

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physical health, being more likely to live alone, and having fewer close relationships (Gardiner et al., 2018). Evidence shows that loneliness is also linked to other health conditions, such as coronary heart disease and stroke, dementia, suicidality, as well as increased risk of early mortality (Holt-Lunstad et al., 2015; Kuiper et al., 2015; Stickley & Koyanagi, 2016; Valtorta et al., 2016).

Loneliness has also been associated with increased costs, largely driven by health and social care resource use (Mihalopoulos et al., 2019). It has been hypothesised that lonely people are more likely to visit physicians to meet their need for interaction and interpersonal stimulation (Gerst-Emerson & Jayawardhana, 2015). There is an even greater increase in health care spending if lonely older adults develop other health conditions, such as depression, which incur substantial cost. Therefore, there is a compelling case for addressing loneliness to prevent depression in older adults and to mitigate the subsequent adverse health and economic impacts.

Several reviews have examined the effectiveness of interventions to reduce loneliness in older adults (Cattan et al., 2005; Cohen-Mansfield & Perach, 2015; Dickens et al., 2011; Gardiner et al., 2018; Hagan et al., 2014; Masi et al., 2011; O'Rourke et al., 2018). Educational group interventions focused on social networks maintenance and enhancement that target specific at-risk groups have been found to be effective (Cattan et al., 2005). Older women are considered at risk of loneliness as they are more likely to be widowed, living alone, and often experience greater physical and emotional vulnerability compared to men (Martina et al., 2012). One intervention that addresses loneliness in older women is the *Friendship Enrichment Programme* (FEP), an educational program with a psychosocial element, which is based on principles of re-evaluation counselling, feminist counselling, and relational competence (Martina & Stevens, 2006; Martina et al., 2012, 2018; Stevens & van Tilburg, 2000; Stevens, 2001; Stevens et al., 2006). The FEP posits that improved friendships increase the availability of support and companionship from peers, which will then lead to reductions in loneliness and improved subjective wellbeing (Martina & Stevens, 2006).

There is also an increasing body of evidence suggesting that computer and internet interventions can reduce loneliness in the older adult population (Chen & Schulz, 2016; Choi et al., 2012; Cohen-Mansfield & Perach, 2015; Morris et al., 2014). The opportunity to communicate regardless of physical distance provides the ability to maintain relationships with friends and family, and thereby gain social support (Slegers et al., 2008). However, it is important not to view internet and computer training as stand-alone tools but to consider them in the context in which training is provided. There is evidence that internet and computer training provided *as part* of a volunteer visiting program is effective in reducing loneliness in older adults (Fokkema & Knipscheer, 2007; Jones et al., 2015). Evidence for reducing loneliness was not found when professional trainers were used (Slegers et al., 2008; White et al., 2002), suggesting that the social contact may drive the intervention effect.

A previous study in the United Kingdom assessed the cost-effectiveness of an internet and computer training intervention in lonely older adults and the FEP in lonely older women (Mallender et al., 2015). The study found that internet and computer training was cost-effective at £15,962 per quality-adjusted life year (QALY) gained, while the FEP was cost saving. However, the study did not model the cost-effectiveness of internet and computer training as part of a volunteer visiting program, which has been found to be more effective (Fokkema & Knipscheer, 2007; Jones et al., 2015). It also remains unclear if such interventions represent good 'value for money' within the Australian context, alongside other implementation considerations. The aim of the current study was to evaluate the cost-effectiveness of the FEP and a volunteer-led internet and computer training (VICT) intervention in reducing loneliness and subsequent depression for older adults within the Australian context. The current study formed part of a larger program of work, funded by the National Mental Health Commission of Australia, which aimed to evaluate the return on investment credentials

of ten preventive interventions for mental health across the life span (Commission, 2020).

2. Material and methods

A population-based Markov model was built in TreeAge Pro Healthcare software (TreeAge Pro 2019, 2019) to evaluate the cost-effectiveness of the FEP and VICT interventions. To ensure comparability across the ten interventions modelled for the broader project, similar approaches to modelling were used, which were largely based on prior 'Assessing Cost Effectiveness' work for priority setting (Mihalopoulos et al., 2011). A population level model using a cost-utility analysis framework, where outcomes are expressed in terms of QALYs was developed. An incremental cost-effectiveness ratio (ICER) was calculated for each intervention, which is the difference in costs between the intervention and the comparator groups, divided by the corresponding difference in QALYs. A willingness-to-pay threshold of A$50,000 per QALY gain was used to determine if an intervention was cost-effective (George et al., 2001). Additionally, a return-on-investment (ROI) analysis was conducted, where the cost savings resulting from an intervention are directly compared to the cost of the intervention. This ratio is technically considered a benefit-cost ratio, where total discounted cost savings are divided by the total discounted costs. Interventions with ROI ratios greater than 1 are considered cost-effective, as they denote aggregate cost savings that exceed the cost of an intervention. QALYs and other health benefits were not monetised and excluded from the ROI ratio.

2.1. Description of the interventions and their effectiveness

2.1.1. Friendship enrichment programme (FEP)

The FEP has been developed in the Netherlands to help women aged 55 and over to improve their wellbeing and alleviate loneliness by enhancing current friendships or developing new friendships (Stevens & van Tilburg, 2000). The FEP consists of 12 lessons that focus on topics related to friendship (i.e., expectations of friendship, early experience in friendship, self-evaluation as a friend, making new friends, improving existing friendships, and setting goals in friendship) (Stevens & van Tilburg, 2000). Each lesson is supplemented by practicing skills, role playing, and a homework assignment. The lessons are delivered to a group of 8-12 women. Six months after the program, participants meet again to evaluate their success and redefine goals for their future (Martina & Stevens, 2006). The program is usually delivered in adult education centres, community mental health centres or social service agencies (Stevens & van Tilburg, 2000) by a teacher who must have a higher professional education level (e.g., social work) or have completed university-level psychology training (van de Maat, 2010).

Intervention effectiveness was sourced from two previous quasi-experimental studies (Martina & Stevens, 2006; Stevens & van Tilburg, 2000). Loneliness in both studies was measured using the 11-item de Jong Gierveld scale that categorizes people as not lonely (0-2), moderately lonely (3-8), severely lonely (9-10), and very severely lonely (11) (de Jong Gierveld & van Tilburg, 2017). Given that the studies only reported a numerical point reduction in loneliness, a threshold approach, applied in a previous modelling study (Mallender et al., 2015), was used to estimate the proportion of lonely women not becoming lonely. Thereby, the proportion of women in the relevant intervention/control group who score below the cut-off point of two (indicative of not lonely) was calculated. In the more recent study (Martina & Stevens, 2006), loneliness in both groups was reduced; for the intervention group from 7.5 (SD = 3.5) to 6.6 (SD = 3.6) and from 5 (SD = 4.2) to 4.7 (SD = 3.9) for the control group, although the difference between these declines was not statistically significant. However, the authors noted that the decrease in loneliness over a period of six months was smaller compared to the pilot study that had a 12-month follow-up period (Stevens & van Tilburg, 2000). In the pilot study,

loneliness decreased from 7.2 (SD = 2.9) to 4.5 (SD = 3.2) for the intervention group and from 7.1 (SD = 3.1) to 5.5 (SD = 3.7) for the control group. As it was assumed that it may take longer than six months to show reductions in loneliness, a combined estimate of 11.00% (SD = 0.10) decrease in the number of lonely women not becoming lonely was used in the present model for the intervention and 6.45% (SD = 0.08) for the comparator. The intervention effect was assumed to be the same for all age-groups in the absence of further evidence.

2.1.2. Volunteer-led internet and computer training (VICT)

VICT was modelled as an add-on component of the current Community Visitors Scheme (CVS) in Australia. The CVS is available to recipients of residential aged care services or Home Care Packages subsidised by the Australian Government who have been identified by their aged care provider as being at risk of isolation or loneliness (Australian Government, 2014). Individuals who would benefit from the companionship of a regular community visitor can be referred by family members, a friend, or self-identify. The Australian Government funds organisations (referred to as CVS auspices) to recruit and train volunteer visitors, whose primary role is to provide friendship and companionship to the socially isolated consumer. CVS auspices provide volunteer visitors with a basic training/orientation on their role and obligations. There are currently three types of visits available by a volunteer visitor: 1) one-on-one visits to a care recipient in a residential aged care home; 2) one-on-one visits to a care recipient of a Home Care Package in their home; or 3) group visits that consist of two or more care recipients at the same time in a residential aged care home.

The intervention delivery reflects the process of two studies from which effectiveness was sourced (Fokkema & Knipscheer, 2007; Jones et al., 2015), consisting of two components. First, special training is delivered to volunteer visitors (i.e., 10 volunteers per group) by an IT trainer on basic computer and internet use, as well as on more advanced topics, such as online communication, shopping and entertainment. It was assumed that 24 h of total training is provided to volunteer visitors (Woodward et al., 2013). The second component of the intervention involves sharing of the computer and internet knowledge with the CVS recipient. It was assumed that computer and internet training is delivered as part of the 20 visits per year that an 'active visitor' should undertake (i.e., no increase in the number of general volunteers visits and all visits are directed towards internet and computer training). For group visits, a group size of six residents per volunteer was assumed. The intervention further encompasses the provision of a computer, basic computer software, and internet access to CVS recipients.

Intervention effectiveness was sourced from two previous quasi-experimental studies (Fokkema & Knipscheer, 2007; Jones et al., 2015). Loneliness was measured using the 6-item and the 11-item de Jong Gierveld scale (de Jong Gierveld & van Tilburg, 2017) and the same threshold approach was used to estimate the proportion of lonely people not becoming lonely. The first study reported that loneliness in the intervention group decreased from 8.1 (SD = 2.4) to 5.8 (SD = 3.9), whereas in the control group loneliness reduced only from 8.2 (SD = 1.9) to 7.5 (SD = 2.6) (Fokkema & Knipscheer, 2007). The reduction was only significant in the intervention group. The second study found a significant reduction in loneliness from 2.4 (SD = 1.6) to 1.8 (SD = 1.6) in those receiving the intervention (Jones et al., 2015). Combining the intervention effect estimates from the two studies, resulted in 13.50% (SD = 4.0) of the lonely older adults becoming not lonely. The reduction in the number of lonely older adults for the comparator reflected reductions in the control group of the study by Fokkema & Knipscheer (2007), which was estimated to be 1.67%. No control group was included in the study by Jones et al., (2015).

2.2. Model structure

The model structure is provided in Fig. 1, which shows that at the end of each 1-year time period, individuals may move between three health states (lonely, not lonely or dead). The probability of developing depression was also included within each of the health states. The model follows the eligible cohort over a 5-year time horizon. The 5-year time horizon was chosen because it was a sufficient length of time to evaluate the benefit impacts of preventive interventions based on previous evidence (Le et al., 2021). The cycle length in the model was one year and the half-cycle correction was applied to account for transitions that occur midway through the cycle. Complete details on the model input parameters and uncertainty ranges are provided in Appendix 1.
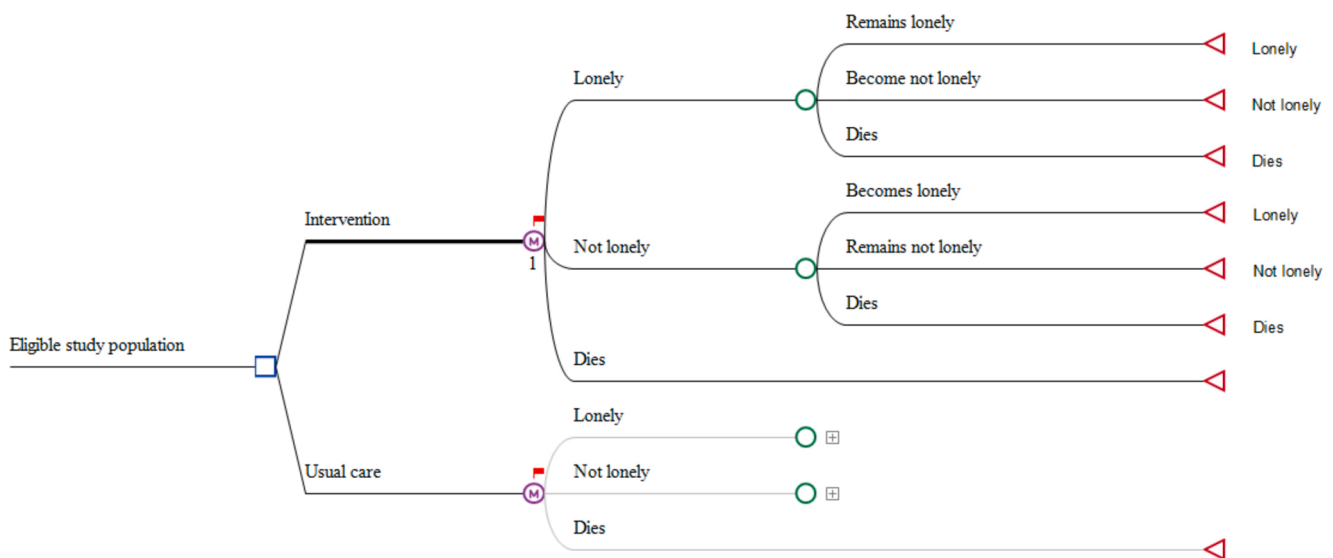

Fig. 1. Markov model structure
A decision node (square) indicates a choice facing the decision maker. A chance node (circle) represents an event which has multiple possible outcomes and is not under the decision maker's control. A terminal node (triangle) denotes the endpoint of a scenario. The purple Markov node represents the start of the Markov process, where each branch of the Markov node represents a health state. The branches from the health states represent possible events that could occur during a cycle started in that health state. Note: To account for the impact of loneliness on depression, the 'lonely' and 'not lonely' health states involve differing probabilities of developing depression.

2.2.1. Comparator

The comparator for both interventions assumed that no intervention is provided. This corresponds to the control group scenarios from which evidence was sourced and was deemed to be appropriate, given that it is unclear which other services lonely older adults in Australia are using.

2.2.2. Eligible study population

Appendices 2 and 3 show how the eligible populations were estimated. The eligible population for the FEP intervention included women aged 55 years and above (n = 3,579,586) (Australian Government, 2018), residing in private dwellings (88%) (Australian Bureau of Statistics, 2017a) who experience loneliness (19%) (Relationships Australia, 2018). Assuming a participation rate of 30%, the total cohort was estimated at 163,229 women. For the VICT intervention, the eligible population comprised recipients of the current CVS program (n = 270, 490 in residential care; n = 116,843 receiving home care packages) (Australian Government, 2018), who are considered lonely (19%), who have no previous computer and internet experience (21%) but show interest in accessing the internet (31%) (Australian Communications and Media Authority, 2016). This resulted in 4,791 individuals. A recent report of the CVS indicated that the majority of CVS funding is directed to residential one-on-one visits rather than residential group visits (Australian Healthcare Associates, 2017). As such, the model assumed that of the recipients of residential aged care services, 60% receive one-to-one and 40% receive residential group visits.

2.2.3. Transition probabilities

Transition probabilities are presented in Appendix 1. The model cohort commenced in the 'lonely' state. The numbers moving from the 'lonely' state to the 'not lonely' state was determined by the intervention effect. The 1-year probability of becoming 'lonely' if 'not lonely' in subsequent transitions was assumed to be 16.7% (SD = 2.3) for the FEP intervention, based on loneliness rates of those aged 55 and over, whereas for the VICT intervention (65 years and above) this was assumed 19.0% (Relationships Australia, 2018). To determine the subsequent impact of loneliness on depression associated with the 'lonely' and 'not lonely' states, a meta-analysis was used, which reported that loneliness had a moderate and significant effect on depression ($r = 0.49$ [$p < 0.1$, 95% CI: 0.39-0.59]) (Erzen & Cikrikci, 2018). This correlation coefficient effect size was first converted into an Odds Ratio (OR) (Polanin & Snistveit, 2016) and then into a relative risk (RR) using the Cochrane method (Lee et al., 2018). The resultant estimated RR for developing depression was 5.5 if 'lonely'. The probability of developing depression when 'not lonely' was estimated to be 7.9% for intervention one and 21.7% for intervention two, which included residential aged care residents who have higher levels of depression (Australian Institute of Health and Welfare, 2013; Pirkis et al., 2009).

The increased risk of mortality when experiencing loneliness was derived from a meta-analysis showing that lonely people had a higher likelihood of mortality than people who were not lonely (OR = 1.26, 95% CI: 1.04 - 1.53) (Holt-Lunstad et al., 2015). The Cochrane method was used to convert the OR into a RR (Lee et al., 2018), which was estimated at 1.24 (95% CI: 1.04-1.48). The assumed control risk required for this conversion was based on an estimate obtained from the Global Burden of Disease study 2016 in relation to the global, 1-year mortality probability from all causes among those aged 70+ years during 2016 (Institute for Health Metrics and Evaluation (IHME), 2019). The background mortality rate used in the model was derived using population and mortality data from the Australian Bureau of Statistics for female aged 55+ years for FEP and for older adults aged 65+ for VICT (Australian Bureau of Statistics, 2017c).

2.3. Costs

Intervention costs and cost savings arising from the two interventions were estimated using a partial societal perspective, which included healthcare costs, productivity costs for working women in the FEP model and volunteers' time costs in the VICT model. All salary costs included 30% on-costs (i.e., overheads due to superannuation, leave and other employee entitlements). Costs were discounted at an annual rate of 3% and inflation-adjusted to 2016 prices using relevant health price deflators (Australian Institute of Health and Welfare, 2019).

2.3.1. Costs of the FEP intervention

The cost of the FEP were calculated by summing the cost of advertisement, training, and delivery of the intervention, which were one-off costs that only applied in the first year of the model. A detailed calculation of the intervention costs is provided in Appendix 4. Advertising costs included an advertisement in the local press and the cost of placing leaflets in general practitioner waiting rooms. The intervention was delivered by social workers, who require five hours of training to familiarize themselves with FEP content. Each social worker delivered the intervention to three groups with an average size of 10 women per group. It was assumed that: 60% of lessons were delivered in facilities with spare rooms that were available at no additional cost; while 40% of the lessons involved additional costs for venue hire. The cost of producing intervention materials was also included. The total cost of the FEP was estimated to be A$155 per person.

2.3.2. Cost of the VICT intervention

The cost of the VICT intervention included the cost of volunteer training, equipment, and intervention delivery. Detailed estimates of VICT intervention costs are provided in Appendix 5. It was assumed that volunteer visitors would require 24 h of training on internet and computer use (Woodward et al., 2013). This was provided to a group of 10 volunteer visitors by an IT trainer. Facilities for delivering IT training were assumed to be available, given that volunteer visitors already receive other types of training under the general CVS program. The time spent by volunteers receiving training was coasted at an hourly rate that reflects 25% of the earnings in people aged 55+ years (Australian Bureau of Statistics, 2017b). The cost of information booklets comprised both the cost of production and the time incurred by IT trainers' to develop these materials. The intervention further encompassed the provision of a physical computer and accompanying software. It was assumed that 30% of residential aged care facilities were already equipped with computers; necessitating additional computer purchases for the remaining 70% of facilities. Internet service was assumed to be available in all residential aged care facilities and provided free of charge for those receiving 1:1 home visits. This assumption was made in light of current government initiatives, such as *Tech Savvy Seniors* (Telstra, n/a) or *Be Connected* (Australian Government, n.d.), which aim to increase confidence in older adults to use technology. No additional volunteer time was coasted, as the intervention was assumed to be delivered as part of the 20 visits per year that an 'active visitor' should undertake. Room space for intervention delivery was assumed to be readily available. Intervention costs also comprised information booklets for CVS recipients. The total cost of the VICT intervention was estimated to be A$464 per person (residential 1:1 = A$405; Residential group = A$100; Home 1:1 = A$882).

2.3.3. Cost savings

The total cost savings arising from the FEP and VICT interventions were estimated as the aggregate sum of all cost savings attributable to reduced healthcare costs associated with fewer physician consultations (Gerst-Emerson & Jayawardhana, 2015) and fewer self-harm hospitalisations due to the avoidance of loneliness (Stickley & Koyanagi, 2016). Unit costs for physician consultations were obtained from the Medicare Benefits Schedule (MBS, n.d.); while unit costs for self-harm hospitalisations were sourced from the Independent Hospital Pricing Authority (IHPA, n.d.). In addition, cost savings due to avoidance of treatment for depression were included based on the average annual healthcare cost attributable to a diagnosed case of depression (Lee et al., 2017). In the

FEP model, productivity gains and job turnover costs associated with depression treatment were also considered for women aged 55-64 years based on estimates from a previous study (Cocker et al., 2017).

2.4. QALY estimates

Utility weights for older adults who are lonely and not lonely were obtained from the Swedish National Study on Aging and Care in the absence of corresponding Australian data (Taube et al., 2013). The mean EQ-5D-3L utility score was 0.75 (SD = 0.20) for not lonely older adults compared to 0.66 (SD = 0.27) for lonely older adults. The impact of loneliness on depression was taken into account by multiplying the probability of developing depression if lonely or not lonely by the utility weight of being depressed, which was estimated to be 0.50 (SD = 0.32) based on the EQ-5D-3L (Serfaty et al., 2009). This approach to estimating the QALY gain impacts has been previously applied in another modelling study (Mallender et al., 2015), with further details provided in Appendix 6. QALYs were discounted at 3% per year.

2.5. Uncertainty and sensitivity analyses

Uncertainty analyses, or probabilistic sensitivity analyses, were undertaken alongside each cost-effectiveness model to account for the uncertainty of key parameters used in the model. Monte Carlo simulation was used to resample values for each input parameter over 3,000 iterations. Input parameters and uncertainty ranges used in the model are presented in Appendix 1. A cost-effectiveness plane was constructed to visually represent model uncertainty. A univariate sensitivity analysis was performed by varying model input parameters by ±10%. Results were presented in a Tornado diagram, which graphs sequentially the parameters with the largest impact on the results. Additional deterministic sensitivity analyses (SA) were also undertaken to test several model assumptions. For the FEP intervention, this included: the consideration of time and travel costs of women (SA1); the exclusion of advertising costs (SA2); increasing the number of social workers undergoing training (SA3); reducing the intervention effect by 50% (SA4); assuming the intervention was delivered by a welfare recreation and community arts worker (SA5); assuming that 1 in 5 lonely women would attend the session with someone else (SA6); removing productivity impacts (SA7), and applying a 3-year time horizon (SA8). For the VICT intervention, three sensitivity analyses were conducted to account for: the cost of internet access for those receiving 1:1 home visits (SA1); reducing intervention effectiveness from 13.5% to 4.4% (SA2), and applying a 3-year time horizon (SA3). A detailed description of each sensitivity analysis is provided in Appendix 7.

2.6. Implementation considerations

While the focus of this study was on cost-effectiveness outcomes, there are other criteria that can influence the degree to which interventions are likely to be rolled out in routine practice. These considerations include equity, sustainability, feasibility, strength of evidence, acceptability, and other potential secondary effects. Implementation considerations were derived following consultation with a group of clinical experts and stakeholders mentioned in the Acknowledgements.

3. Results

Cost-effectiveness results for the FEP intervention are presented in Table 1. The total cost of implementing the intervention was A$25 million (M). The intervention subsequently produced A$72.4M (95% Uncertainty Interval (UI): -731M; 396M) of cost savings after 5 years due to reductions in healthcare treatment costs and productivity gains. The intervention resulted in 7,889 (95% UI: -77,904; 117,568) QALYs after 5 years. The FEP was the dominant strategy, which means that the

Table 1
Cost-effectiveness results for the FEP intervention.

	n = 163,229
Intervention costs [a]	$25,226,570
Total cost savings [b] (95% UI)	-$72,409,307 (-731,580,645 to 396,830,008)
Healthcare cost [b] (95% UI)	-$25,822,764 (-597,783,642 to 351,568,014)
Productivity cost [b] (95% UI)	-$46,586,543 (-276,716,769 to 189,076,376)
Incremental costs [b] (95% UI)	-$47,182,737 (-706,354,128 to 414,572,085)
Incremental QALYs gained (95% UI)	7,889 (-77,904 to 117,568)
ICER ($ per QALY gained)	dominant [c]
ROI (95% UI)	2.87 (-15.43 to 28.92)

[a] No uncertainty was modelled around the input parameters used to calculate this estimate.

[b] A positive value indicates a cost; a negative value indicates cost saving.

[c] A dominant ICER signifies that the intervention is both cost saving and produces more QALYs relative to the comparator. A 95% UI was not presented since uncertainty iterations span all four quadrants of the cost-effectiveness plane.

intervention was found to be less costly and more effective when compared to the comparator. The ROI was estimated to be 2.87 (95% UI: -15.43; 28.92).

The cost-effectiveness results for the VICT intervention are presented in Table 2. The total cost of implementing the intervention was around A$2.2M and the intervention produced A$4.7M (95% UI: -38M; 9.9M) in cost savings after 5 years, resulting in an ROI ratio of 2.14 (95% UI: -4.49; 17.88). The intervention resulted in 1,072 QALYs gained with the corresponding ICER being dominant. Across the three types of volunteer visits, delivering the intervention as part of the residential group visits resulted in the highest ROI ratio (9.89, 95% UI: -20.79; 82.78).

The cost-effectiveness planes for both interventions are presented in Fig. 2. Both planes indicate high levels of uncertainty around costs and QALYs, with only 55% of the iterations for the FEP intervention lying below the Australian willingness-to-pay threshold of A$50,000 per QALY gained and 68% of iterations for the VICT intervention lying below the threshold. The Tornado diagrams in Appendix 8 indicate that the results for both interventions were most sensitive to the utility estimates as well as the treatment effect estimates but the interventions remained cost-effective under the A$50,000 per QALY gain threshold.

3.1. Sensitivity analysis results

Results from the sensitivity analyses are presented in Table 3. For the FEP intervention, the results remained robust under different scenarios, with ROIs above 1. However, when including the time and travel cost of intervention participants for the FEP (SA1), the ICER changed from being dominant to $5,649 per QALY gained and the ROI ratio dropped from 2.87 to 0.62. Excluding productivity impacts (SA7) resulted in a ROI of 1.02, with the ICER remaining dominant. For the VICT, results from the scenario including the cost of internet access for those receiving 1:1 home visits (SA1) and reducing the intervention effect (SA2) resulted in a ROI ratio below 1 (SA1: ROI = 0.47; SA2: ROI = 0.54), which means that the cost of the intervention were greater than the resulting cost savings. The ICERs in both scenarios changed from being dominant to A$4,796 per QALY gained (SA1) and A$3,760 per QALY gained (SA2), which is still considered cost-effective.

3.2. Implementation considerations

The cost-effectiveness results were interpreted alongside several implementation considerations that were identified by stakeholders. These are presented in Table 4. Overall, the strength of evidence on the
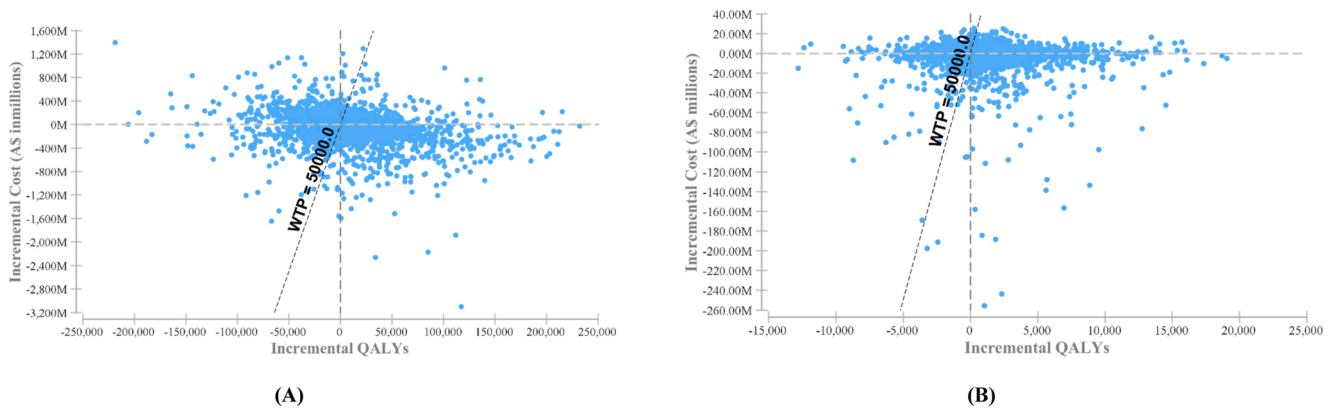
Table 2
Cost-effectiveness results for the VICT intervention.

	All types of visits (n = 4,791)	Residential 1:1 (n = 2,008)	Residential group (n = 1,338)	Home 1:1 (n = 1,445)
Intervention costs [a]	$2,221,930	$812,882	$134,031	$1,275,016
Cost to Government	$1,427,914	$379,154	$85,863	$962,896
Cost to volunteers	$794,016	$433,728	$48,168	$312,120
Cost savings [b] (95% UI)	-$4,747,013 (-39,728,732 to 9,976,587)	-$1,989,564 (-16,651,073 to 4,181,378)	-$1,325,716 (-11,095,187 to 2,786,198)	-$1,431,733 (-11,982,471 to 3,009,010)
Incremental costs [b] (95% UI)	-$2,525,083 (-37,506,802 to 12,198,517)	-$1,176,682 (-15,838,191 to 4,994,261)	-$1,191,685 (-10,961,156 to 2,920,229)	-$156,716 (-10,707,454 to 4,284,027)
Incremental QALYs gained (95% UI)	1,072 (-3,939 to 8,569)	449 (-1,651 to 3,591)	299 (-1,100 to 2,393)	323 (-1,188 to 2,584)
ICER ($ per QALY gained)	dominant [c]	dominant [c]	dominant [c]	dominant [c]
ROI (95% UI)	2.14 (-4.49 to 17.88)	2.45 (-5.14 to 20.48)	9.89 (-20.79 to 82.78)	1.12 (-2.36 to 9.40)

[a] No uncertainty was modelled around the input parameters used to calculate this estimate.

[b] A positive value indicates a cost; a negative value indicates cost saving.

[c] A dominant ICER signifies that the intervention is both cost saving and produces more QALYs relative to the comparator. A 95% UI was not presented since uncertainty iterations span all four quadrants of the cost-effectiveness plane.

(A)

(B)

Fig. 2. Cost-effectiveness planes for (A) the FEP intervention and (B) the VICT.

Table 3
Sensitivity analysis results.

	Total Intervention costs	Cost savings	Incremental costs [a]	Cost per person	Incremental QALYs gained	ICER [b]	ROI
Friendship and Enrichment Program (FEP)							
Base case	$25.2M	$72,409,307	-$47,182,737	$155	7,889	dominant	2.87
SA1: Time and travel costs included	$116.9M	$72,409,307	$44,561,701	$717	7,889	5,649	0.62
SA2: Excluding advertisement cost	$25M	$72,409,307	-$47,349,421	$154	7,889	dominant	2.89
SA3: Increase in the number of trainers	$26.4M	$72,409,307	-$45,964,715	$162	7,889	dominant	2.74
SA4: Reduction in effect by 50%	$25.2M	$37,248,687	-$12,022,169	$155	4,057	dominant	1.48
SA5: Delivered by a welfare recreation and community arts worker	$20.7M	$72,409,307	-$51,668,058	$127	7,889	dominant	3.49
SA6: Additional participants	$25.2M	$46,033,412	-$20,806,842	$155	5,014	dominant	0% = 1.82
		$66,725,958	-$41,499,389		7,269		50% = 2.65
		$86,891,257	-$61,664,687		9,467		100% = 3.44
SA7: Excluding productivity impacts	$25.2M	$25,822,764	-$596,194	$155	7,889	dominant	1.02
SA8: 3-year time horizon	$25.2M	$34,084,915	-$8,858,345	$155	3,653	dominant	1.35
Volunteer-led Internet and Computer Training (VICT)							
Base case	$2.2M	$4,747,013	-$2,525,083	$464	1,072	dominant	2.14
SA1: Internet cost for Home 1:1	$10M	$4,747,013	$5,335,374	$582 [c]	1,072	$4,976	0.47
SA2: Reduction in intervention effect	$2.2M	$1,202,174	$1,019,755	$464	271	$3,760	0.54
SA3: 3-year time horizon	$2.2M	$2,271,562	-$49,633	$464	505	dominant	1.02

[a] A positive value indicates a cost; a negative value indicates cost saving.

[b] A dominant ICER indicates that the intervention is more effective and less costly compared with the comparator.

[c] In addition to the establishment cost of $582, there is an annual fee of $393.06 per person for internet service for those receiving 1:1 home visits.

effectiveness of both interventions was classified as poor, given that effectiveness evidence was sourced from non-randomized controlled trials. A number of potential secondary effects have been identified, suggesting that the cost-effectiveness results may be underestimated. The FEP intervention could potentially result in additional benefits for informal/unpaid carers, such as reducing the physical demands on

Table 4
Implementation considerations *.

	Friendship Enrichment Program (FEP)	Overall rating	Volunteer-led internet and computer training (VICT)	Overall rating
Potential secondary effects	• Benefits to carers • Prevention of other conditions (dementia, stroke, heart disease) by reducing loneliness	**Positive**	• Benefits to volunteers • Prevention of other conditions (dementia, stroke, heart disease) by reducing loneliness	**Positive**
Equity	• Women who are physically impaired or on low income unable to attend the program • Expenses for formal care arrangements for women who provide informal care • The program disadvantages men; online module available for men and women	**Uncertain**	• Poor internet connection in remote areas • Risk of becoming victims of abuse and cybercrime	**Uncertain**
Strength of evidence	• Intervention effectiveness sourced from non-randomized controlled trials	**Negative**	• Intervention effectiveness sourced from non-randomized controlled trials	**Negative**
Acceptability	• Completion rates indicate high acceptability • Presence of psychological distress may create a barrier to engage in such programs without support	**Uncertain**	• Visitors currently fulfil a range of task, including use of technology. Systematic introduction of internet and computer training highly feasible • Older adults may be reluctant to engage with technology	**Uncertain**
Feasibility	• Identifying lonely women remains a challenge; systematic screening of lonely older women required • Potential shortfall of social workers; delivery by welfare recreation and community arts workers may provide an alternative	**Positive**	• Intervention tailored to the CVS program, indicating high feasibility • Low awareness of the CVS and strict eligibility criteria; the CVS program could be made available to recipients of the Commonwealth Home Support Programme • Identification of lonely older adults remains a challenge and could be addressed by systematic screening • More hours of training of volunteers required	**Positive**
Sustainability	• Possible that future delivery of FEP occurs online • Women could continue regular meetings without the presence of the social worker/facilitator	**Uncertain**	• Future generations may have better computer and internet skills	**Uncertain**

*The colour coding of each criterion is an attempt to visually summarise whether these secondary considerations impact on the results in a positive or negative way. 'Positive' indicates that the secondary consideration(s) strengthen the investment case for the intervention; 'Uncertain' signifies that it is not clear whether the secondary consideration(s) provides support to the investment case; and 'Negative' suggests that the secondary consideration(s) do not support the investment case.

* The colour coding of each criterion is an attempt to visually summarise whether these secondary considerations impact on the results in a positive or negative way. 'Positive' indicates that the secondary consideration(s) strengthen the investment case for the intervention; 'Uncertain' signifies that it is not clear whether the secondary consideration(s) provides support to the investment case; and 'Negative' suggests that the secondary consideration(s) do not support the investment case.

carers, and the VICT intervention could have additional benefits to volunteers who deliver the intervention, which were not considered in the model. The acceptability of the intervention for the target population and the feasibility to implement those was positive/uncertain, where in both scenarios the identification of lonely older adults remains a barrier. While for the FEP, a potential shortfall of social workers may compromise the feasibility, there will be also more hours of training of volunteers required for the VICT delivery. Similarly, the sustainability of both interventions in long term and ethical implications remain unclear.

4. Discussion

This study assessed the cost-effectiveness of two interventions (FEP and VICT), with findings showing that both interventions are possibly cost-effective when adopting a willingness to pay threshold of A$50,000 per QALY gain and generate positive returns on their investment. The base case results were robust to assumptions made in the sensitivity analysis. However, wide uncertainty intervals were observed around incremental costs, incremental QALYs and ICERs, where uncertainty iterations span all four quadrants of the cost-effectiveness plane. The high uncertainty reflects the paucity of evidence on the health-related impacts of loneliness, which led to input parameters with very large sampling errors (i.e., statistical dispersion). Transition probabilities used to model intervention effectiveness were sourced from quasi-experimental studies in the absence of well-designed randomised controlled trials. The poor-quality evidence on the impacts of loneliness has been previously discussed, which is dominated by pre-post studies and non-randomized group comparisons with high risk of bias (Masi et al., 2011; Dickens et al., 2011). There is also a lack of consensus on the definition of loneliness, which is often equated to social isolation (Dickens et al., 2011). Unlike most medical conditions, no standard measurement approach currently exists for loneliness, with evidence

indicating that intervention effectiveness is also partly driven by the measurement tool (Masi et al., 2011). To overcome this challenge, in Australia, a guide to measuring loneliness for community organisations has recently been proposed by the national initiative *Ending Loneliness Together*, ensuring a standardized measurement approach to evaluate programs or activities designed to reduce loneliness (Ending Loneliness Together, 2021).

Model results were also sensitive to utility estimates used in deriving QALYs. These were sourced from the Swedish National Study on Aging and Care, where utilities were measured using the EQ-5D-3L (Taube et al., 2013). However, only unadjusted values were reported despite findings showing that those who were lonely experienced more health problems, inlcuding perceived depressed mood (Taube et al., 2013). While the impact of loneliness on depression was taken into account in the model by multiplying the probability of developing depression by the utility weight of being depressed, the impact may have been overestimated, given that utility values for loneliness partly reflected depressive symptoms. On the other hand, the EQ-5D-3L does not capture social-related aspects of quality of life (Richardson et al., 2015) and the utility values used may have underestimated the burden of loneliness. Future research is needed to determine the most appropriate utility measure for loneliness and to estimate the excess utility decrements associated with loneliness.

Consistent with a previous modelling study assessing the cost-effectiveness of the FEP (Mallender et al., 2015), we also found that the intervention was cost saving. Although internet and computer training was found to be cost-effective at £15,962 per QALY gained previously (Mallender et al., 2015), we found that it is cost saving when the training is delivered as part of a volunteer visiting program. The intervention resulted in the highest ROI ratio when training is provided to a group of residents in aged care facilities. It is also important to interpret the results in light of several assumptions made in this study,

such as the provision of internet cost for home 1:1 delivery. When internet costs are included in the intervention cost, the ROI drops below one but the intervention is still considered cost-effective under the A$50,000 per QALY gain threshold. Similarly for the FEP, the ROI ratio drops below one if the time and travel cost of older women attending the program are considered, which needs to be considered when implementing the program. Our results can be considered conservative when compared to the previous study, as our model only considered the impact of loneliness on depression and not on other health conditions, such as dementia, stroke, diabetes and heart disease. However, our model does not distinguish between different types of depression and it is currently unclear whether loneliness is associated with specific types of depression, such as first-episode depression or recurrent depressive disorder. In this context, our model did not take into account the impact of remission and individuals were assumed to remain depressed for the entire cycle length. Despite applying half-cycle correction, this may not truly reflect the duration of depressive symptoms. The use of Markov models is associated with further limitations, as they lack memory whereby each cycle does not account for previous health states experienced by individuals. It is also important to recognize the reciprocal association between loneliness and depression, where depressive symptoms could lead to subsequent loneliness. Current evidence on the reverse causality is mixed (Courtin & Knapp, 2017), although a recent study has shown that loneliness predicts changes in depression but not *vice versa* (Cacioppo et al., 2010). Additionally, the ROI estimates, which were mainly based on costs and cost savings, may also be underestimated, as they did not include monetised health benefits, such as QALY gains. There are also potential secondary outcomes that were not considered, such as positive impacts on the carers of the older adults or benefits for the volunteers. Other important implementation considerations presented in this paper, such as the acceptability, feasibility and sustainability and ethics implications also need to be considered before routine rollout can be recommended.

5. Conclusion

This study modelled two intervention that aim to reduce loneliness in older adults in order to prevent depression. The FEP and VICT intervention were found to be possibly cost-effective and demonstrated positive returns on investment. While implementation appears feasible and acceptable, the current evidence on intervention effectiveness is limited therefore we recommend that such interventions require further evaluations of effectiveness and cost-effectivenss.

Declaration of Competing Interest

The authors report no conflicts of interest.

Appendix 1. Input parameters and uncertainty ranges used in the model

| Parameters	FEP Value (uncertainty range)	VICT Value (uncertainty range)	Uncertainty distribution	Source
Basic parameters				
Simulation population	163,229	4,791	-	Appendix 2 & 3
Starting age	55 years old	65 years old	-	
Discount rate for costs and QALYs	3%	3%	-	
Time period	5 years	5 years	-	
Transition probabilities				
Becoming 'not lonely' if 'lonely' with the intervention	0.1100 (SD = 0.10)	0.1349 (SD = 0.04)	Beta	FEP: (Martina & Stevens, 2006; Stevens & van Tilburg, 2000) VICT: (Fokkema & Knipscheer, 2007; Jones et al., 2015)
Becoming 'not lonely' if 'lonely' without the intervention	0.0645 (SD = 0.08)	0.0167	Beta	FEP: (Martina & Stevens, 2006; Stevens & van Tilburg, 2000) VICT: (Fokkema & Knipscheer, 2007; Jones et al., 2015)
Becoming lonely if not lonely	0.1667 (SD = 0.023)	0.19	Beta	(Relationships Australia, 2018)
Background mortality	0.0149	0.0257	Fixed	(Australian Bureau of Statistics, 2017c)
Developing depression if not lonely	0.0790 (SE = 0.025)	0.2168 (SD = 0.19)	Beta	(Australian Institute of Health & Welfare, 2013; Pirkis et al., 2009)
Risk ratio of developing depression if lonely	5.502 (SE = 0.093)	5.502 (SE = 0.093)	Normal	(Erzen & Cikrikci, 2018)
Suicide attempt and subsequent hospitalization if lonely	0.030	0.030	Fixed	Prevalence of suicide attempts in last 12 months (9.71%) (Stickley & Koyanagi, 2016); at least 1 hospital attendance following suicide attempt (31%) (NHMRC Centre of Research Excellence in Suicide Prevention, 2015)
Suicide attempt and subsequent hospitalization if not lonely	0.000279	0.000279	Fixed	(NHMRC Centre of Research Excellence in Suicide Prevention, 2015; Stickley & Koyanagi, 2016)
Risk ratio of dying if lonely	1.240 (SE = 0.05)	1.240 (SE = 0.05)	Normal	(Holt-Lunstad et al., 2015)
Utility weights				
Being lonely	0.66 (SD = 0.27)	0.66 (SD = 0.27)	Beta	(Taube et al., 2013)
Not being lonely	0.75 (SD = 0.2)	0.75 (SD = 0.2)	Beta	(Taube et al., 2013)
Being depressed	0.5 (SD = 0.32)	0.5 (SD = 0.32)	Beta	(Serfaty et al., 2009)
Resource use and cost				
Cost of intervention	*	*	Fixed	Appendix 4 & 5
Number of doctor visits associated with being lonely	10.39 (SD = 11.41)	10.39 (SD = 11.41)	Gamma	(Gerst-Emerson & Jayawardhana, 2015)

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Parameters	FEP Value (uncertainty range)	VICT Value (uncertainty range)	Uncertainty distribution	Source
Number of doctor visits if not lonely	9.22 (SD = 10.2)	9.22 (SD = 10.2)	Gamma	(Gerst-Emerson & Jayawardhana, 2015)
Cost of depression cases	$ 834.00 (SD = 2181)	$ 834.00 (SD = 2181)	Gamma	(Lee et al., 2017)
Cost of doctor visits	$ 84.67	$ 84.67	Fixed	Weighted average score of MBS items for GP, Psychologist, Psychiatrist, Allied Health
Cost of self-harm associated hospitalization	$ 2,623.66	$ 2,623.66	Fixed	Weighted average score of DRG X64A and X64B
Annual productivity cost associated with depression	$2,754 (SE = 0.19)	-	Gamma	(Cocker et al., 2017)
Annual job turnover costs associated with depression	$7,183 (SE = 0.26)	-	Gamma	(Cocker et al., 2017)

*Intervention cost vary across different scenarios.

Appendix 2. Flowchart of outlining the estimation of the eligible population for the FEP
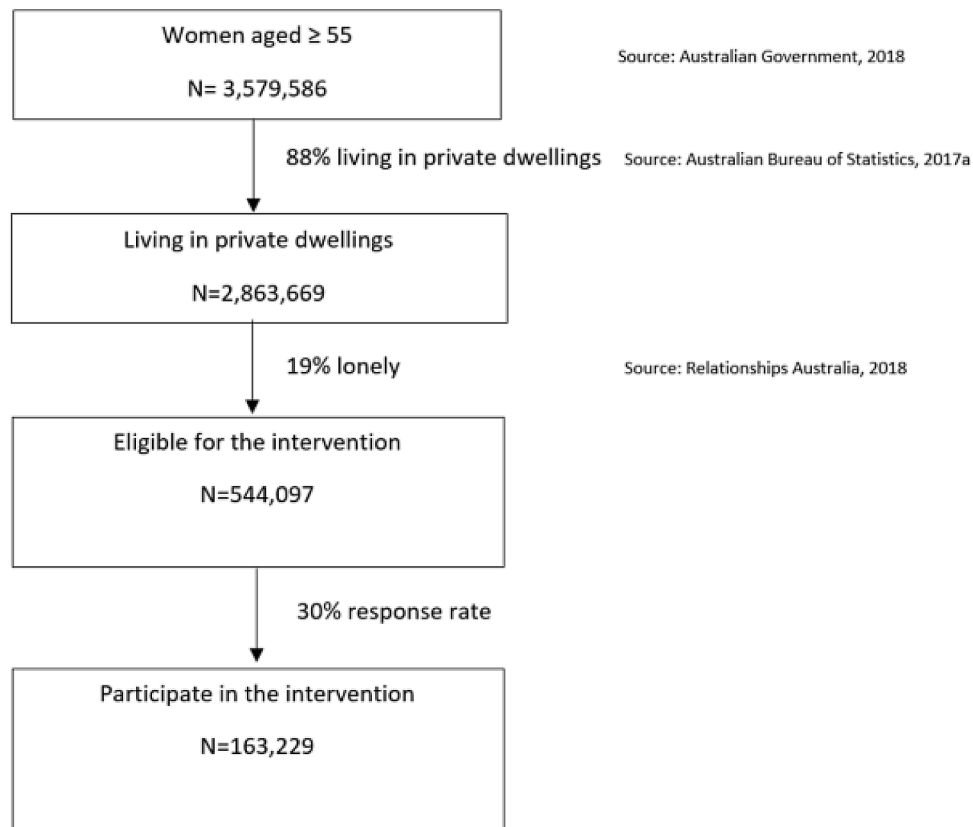
Appendix 3. Flowchart of outlining the estimation of the eligible population for the VICT
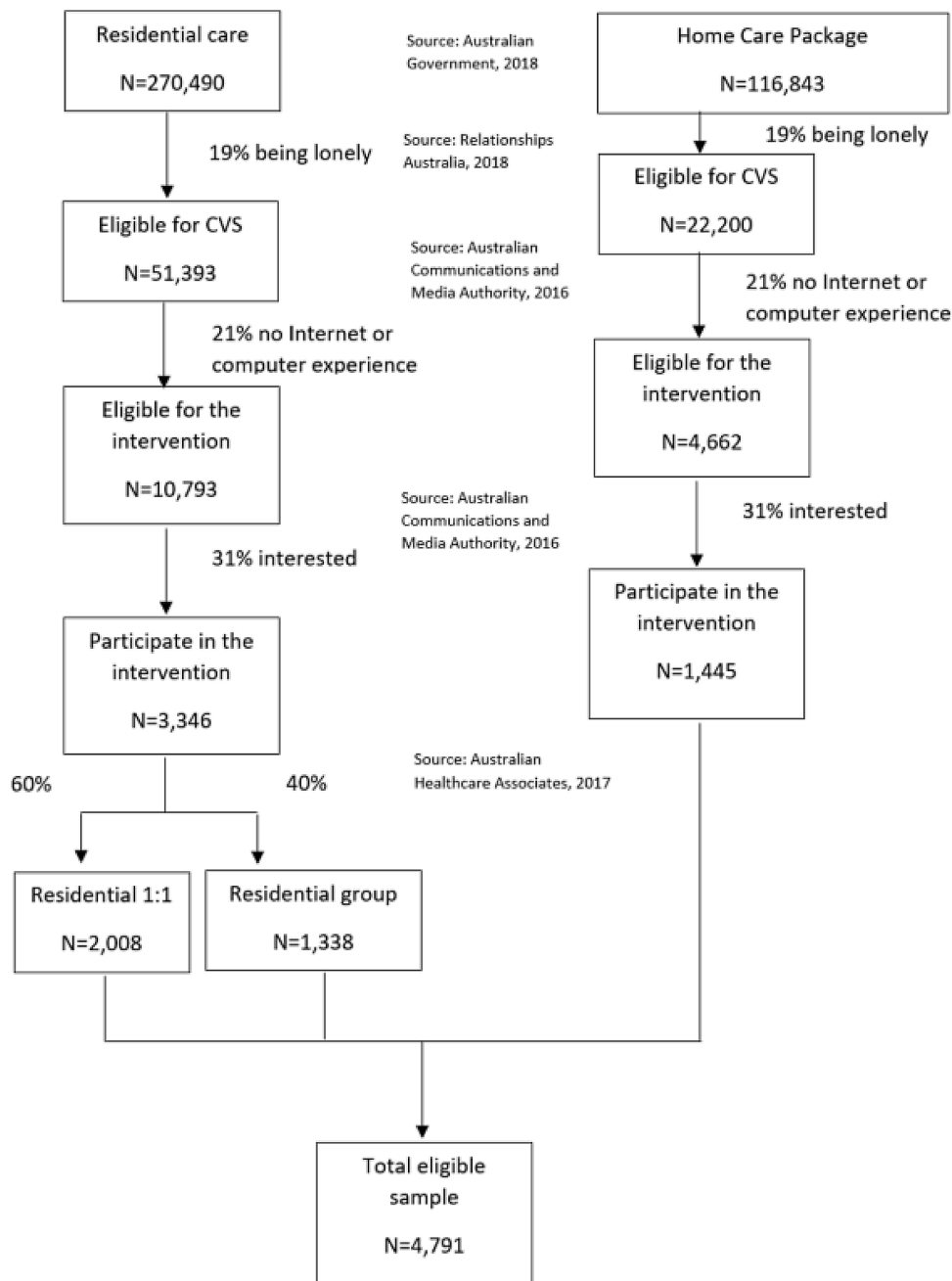
Appendix 4. Calculation of the intervention cost for the FEP

Cost item	Value	Quantity	Unit cost	Source/notes
Advertisement cost				
Cost of advert in local press	$ 5,957.60	2	$ 2,978.80	The Australian (https://www.newscorpaustralia.com/wp-content/uploads/2017/07/The-Australian-Rate-Card-FY1819.pdf) It was assumed that 2 adverts are necessary (no information mentioned in the paper)
Printing of leaflets	$ 46,482.00	387,350	$ 0.12	7747 GP practices in Australia (Tran et al., 2018) 7747 × 100 leaflets per GP practice = 387350
Parcel and postage of leaflets to GP practices	$ 113,745.33	7747	$ 14.68	Mailing box (set of 20) = $35.65/20 = 1.7825 per box Mailing = $12.90 (https://try.sendle.com/pricing) Total = $14.6825
Admin person	$499.85	10	$49.99	"ABS: weekly cash earning of Contract, program and project administrators (5111) = $1457.20 or $38.45 per hour.
Total advertisement cost	**$166,684.78**			

(*continued*)

Cost item	Value	Quantity	Unit cost	Source/notes
Cost of training for social workers				
Trainer cost for 5 h training	$ 1,218,022.26	5441	$ 223.86	ABS: weekly cash earning of Social worker (2725) = $1,287.20 or $34.44 per hour. +30% on-costs = $44.772 / 5 h of training = $223.86 / Assumption: 1/3 of total required social workers (16323) will deliver the intervention to multiple groups = 5441 social workers
Manual FEP	$ -		$ -	Provided free of charge
Total cost of training	**$1,218,022.26**			
Delivery of FEP				
Trainer cost	$ 19,001,147.26	16323	$ 1,164.07	ABS: weekly cash earning of Social worker (2725) = $1,287.20 or $34.44 per hour. +30% on-costs = $44.772 / 1 session x 2 h = $89.544 / 12 sessions (+1 final meeting) = 1,164.072
Material	$ 3,754,290.00	16323	$ 230.00	About 150 Euro ~x223Chttps://www.movisie.nl/sites/movisie.nl/files/2018-03/Methode beschrijving-zin-in-vriendschap.pdf
Venue hire	$ 1,086,425.60	6529	$ 166.40	$6.40 per hour (https://www.melbourne.vic.gov.au/community/libraries/using-the-library/bookable-spaces/pages/city-library-group-study-room.aspx) / For 2 h x 13 (12 sessions + final meeting) = 26 h per group / $6.40 × 26 = $166.4 / It was assumed that 60% of the lessons are delivered in facilities that have existing rooms that can be used free of charge, so only 6529 out of 16,323 group sessions require venue hire
Total cost of delivery	**$23,841,862.86**			
Sensitivity (SA1) - time cost of participants				
Time cost lessons	$ 38,195,586.00	163229	$ 234.00	25% of hourly rate (ABS: weekly cash earning in >55 years in 2016 = 1372.4 (~x223C$36 per hour, (25% = 9$) to attend the training. / 1 h = $9 / 12 lessons + final meeting x 2 h = $234
Time cost homework	$ 35,257,464.00	163229	$ 216.00	25% of hourly rate (ABS: weekly cash earning in >55 years in 2016 = 1372.4 (~x223C$36 per hour, (25% = 9$) to attend the training. / 12 homework x 2 h = $216
Travel cost	$ 18,291,441.74	163229	$ 112.06	$8.62 per session / 13 sessions = 112.06
Total time and travel cost	**$91,744,491.74**			
Sensitivity (SA3) - Cost of training				
Trainer cost for 5 h training	$ 2,436,044.52	10882	$ 223.86	ABS: weekly cash earning of Social worker (2725) = $1,287.20 or $34.44 per hour. +30% on-costs = $44.772 / 5 h of training = $223.86 / Assumption: 2/3 of total required trainers (16323) will deliver the intervention to multiple groups = 10882 trainers
Manual FEP	$ -		$ -	Provided free of charge
Total cost of training	**$ 2,436,044.52**			
Sensitivity (SA5) - Cost of training and intervention delivery				
Trainer cost	$947,822.20	5441	$174.20	ABS: weekly cash earning of a welfare recreation and community arts worker (2726) = $1,000.30 or $26.80 per hour; +30% on-costs = $34.84 / 5 h of training = $174.20 / Assumption: 1/3 of total required trainers (16323) will deliver the intervention to multiple groups = 5441 trainers
Manual FEP	$-		$-	Provided free of charge
Delivery cost by a welfare recreation and community arts worker	$14,786,026.32	16323	$905.84	ABS: weekly cash earning of a welfare recreation and community arts worker (2726) = $1,000.30 or $26.80 per hour. +30% on-costs = $34.84 / 1 session x 2 h = $69.68 / 12 sessions (+1 final meeting) = $905.84
Venue hire	$1,086,425.60	6529	$166.40	$6.40 per hour (https://www.melbourne.vic.gov.au/community/libraries/using-the-library/bookable-spaces/pages/city-library-group-study-room.aspx) / For 2 h x 13 (12 sessions + final meeting) = 26 h per group / $6.40 × 26 = $166.4 / It was assumed that 60% of the lessons are delivered in facilities that have existing rooms that can be used free of charge, so only 6529 out of 16,323 group sessions require venue hire
Material	$3,754,290.00	16323	$230.00	About 150 Euro ~x223Chttps://www.movisie.nl/sites/movisie.nl/files/2018-03/Methode beschrijving-zin-in-vriendschap.pdf
Total cost of training	**$20,574,564.12**			
Total intervention cost (Base case)				
TOTAL	**$ 5,226,517.24**			
Cost per person	$ 154.55			
Total intervention cost - sensitivity analysis (SA1) time cost				
TOTAL	$ 116,971,008.98			
Cost to Government	$ 25,226,517.24			
Cost to Individuals	$ 91,744,491.74			
Cost per person	$ 716.61			
Total intervention cost - sensitivity analysis (SA2) - no advertisement cost				
TOTAL	$ 25,059,885.12			
Cost to Government	$ 25,059,885.12			
Cost to Individuals	$ -			
Cost per person	$ 153.53			

(continued)

Cost item	Value	Quantity	Unit cost	Source/notes
Total intervention cost - sensitivity analysis (SA3) - number of trainers				
TOTAL	$ 26,444,539.50			
Cost to Government	$ 26,444,539.50			
Cost to Individuals	$ -			
Cost per person	$ 162.01			
Total intervention cost - sensitivity analysis (SA5) - welfare, recreation and community arts worker				
TOTAL	$ 20,741,248.90			
Cost to Government	$ 20,741,248.90			
Cost to Individuals	$ -			
Cost per person	$ 127.07			

Appendix 5. Calculation of the intervention cost of the VICT

Cost item	Value	Unit (hours)	Unit cost	Source/notes	Residential 1:1 (n = 2008)		Residential group (n = 1338) (6 per volunteer)		Home 1:1 (n = 1445)		Total
					#	Total	#	Total	#	Total	
Volunteer training (24h training over 6 weeks)											
Cost of trainer arranged by CVS auspice (24h)/ site of 10 volunteers	$49.99	24	$1199.64	Training time 24 h (Woodward et al., 2013) Trainer rate ABS 3131 ICT support technician = $1,349.00 per week or $38.45 per hour + 30% on-costs = $49.985	201	$ 241,127.64	22	$ 26,392.08	145	$ 173,947.80	$ 441,467.52
Volunteers' time	$9.00	24	$ 216.00	25% of hourly rate (ABS: weekly cash earning in >55 years in 2016 = 1372.4 (~x223C$36 per hour, (25% = 9$) to attend the training	2008	$ 433,728.00	223	$ 48,168.00	1445	$ 312,120.00	$ 794,016.00
Training material: time	$49.99	4	$ 199.96	Trainer's time to prepare the booklet	201	$ 40,191.96	22	$ 4,399.12	145	$ 28,994.20	$ 73,585.28
Training material print	$10.00	1	$10.00	Printing of 1 booklet per volunteer	2008	$ 20,080.00	223	$ 2,230.00	1445	$ 14,450.00	$ 36,760.00
Class room for training	$0	0	0	Assumed to be available, as training is already provided to volunteers as part of the CVS	0	$ -	0	$ -	0	$ -	$ -
Total training cost						$ 735,127.60		$ 81,189.20		$ 529,512.00	$ 1,345,828.80
Equipment for intervention delivery											
Computer	$411.79	1	$ 411.79	HP 19.5" All-in-One Desktop PC C416A from Officeworks ($425 ~x223C 2016: $411.79)	114	$ 46,944.06	78	$ 32,119.62	1445	$ 595,036.55	$ 674,100.23
Software (MS-Office etc.)	$ 94.13	1	$ 94.13	Microsoft office package	114	$ 10,730.82	78	$ 7,342.14	1445	$ 136,017.85	$ 154,090.81
Set-up	$ -	0	$ -	Assumed no costs for setting up	0	$ -	0	$ -	0	$ -	$ -
Total equipment cost						$ 57,674.88		$ 39,461.76		$731,054.40	$828,191.04
Intervention delivery											
Room space	$ -	0	$ -	Assumed to be available	0	$ -	0	$ -	0	$ -	$ -
Volunteers' time	$ -	0	$ -	same in both groups	0	$ -	0	$ -	0	$ -	$ -
Provision of training material	$ 10.00	1	$ 10.00	Printing of 1 booklet	2008	$ 20,080.00	1338	$ 13,380.00	1445	$ 14,450.00	$ 47,910.00
Trouble-shooting	$ -	0	$ -	Assumed to be resolved during visit. If volunteers don't know how to resolve, support is provided by auspices	0	$ -	0	$ -	0	$ -	$ -
Total delivery cost						$ 20,080.00		$ 13,380.00		$ 14,450.00	$ 47,910.00
Total intervention cost											
Total						$812,882.48		$134,030.96		$1,275,016.40	$2,221,929.84
Cost to Government						$379,154.48		$85,862.96		$962,896.40	$1,427,913.84
Cost to Individuals						$433,728.00		$48,168.00		$312,120.00	$794,016.00
Cost per person						**$404.82**		**$100.17**		**$882.36**	**$463.77**
Sensitivity analysis (SA1) – Internet costs incorporated for those receiving 1:1 home visits											

(continued)

Cost item	Value	Unit (hours)	Unit cost	Source/notes	Residential 1:1 (n = 2008)		Residential group (n = 1338) (6 per volunteer)		Home 1:1 (n = 1445)		Total
					#	Total	#	Total	#	Total	
Total training cost						$735,127.60		$81,189.20		$529,512.00	$1,345,828.80
Total equipment cost						$57,674.88		$39,461.76		$1,299,026.10	$1,396,162.74
Total delivery cost						$20,080.00		$13,380.00		$14,450.00	$47,910.00
Total						$812,882.48		$134,030.96		$1,842,988.10	$2,789,901.54
Cost per person						$404.82		$100.17		$1,275.42	$582.32

Appendix 6. QALY calculation

The annual QALYs for the lonely and not lonely states were calculated as follows:

$$QALY_{lonely} = N_{lonely} \text{ x } \left[\left[UW_{lonely} \times \left(1 - P_{depressed \mid lonely} \right) \right] + \left[UW_{depressed} \times \left(P_{depressed \mid lonely} \right) \right] \right]$$

$$QALY_{not\ lonely} = N_{not\ lonely} \text{ x } \left[\left[UW_{not\ lonely} \times \left(1 - P_{depressed \mid not\ lonely} \right) \right] + \left[UW_{depressed} \times \left(P_{depressed \mid not\ lonely} \right) \right] \right]$$
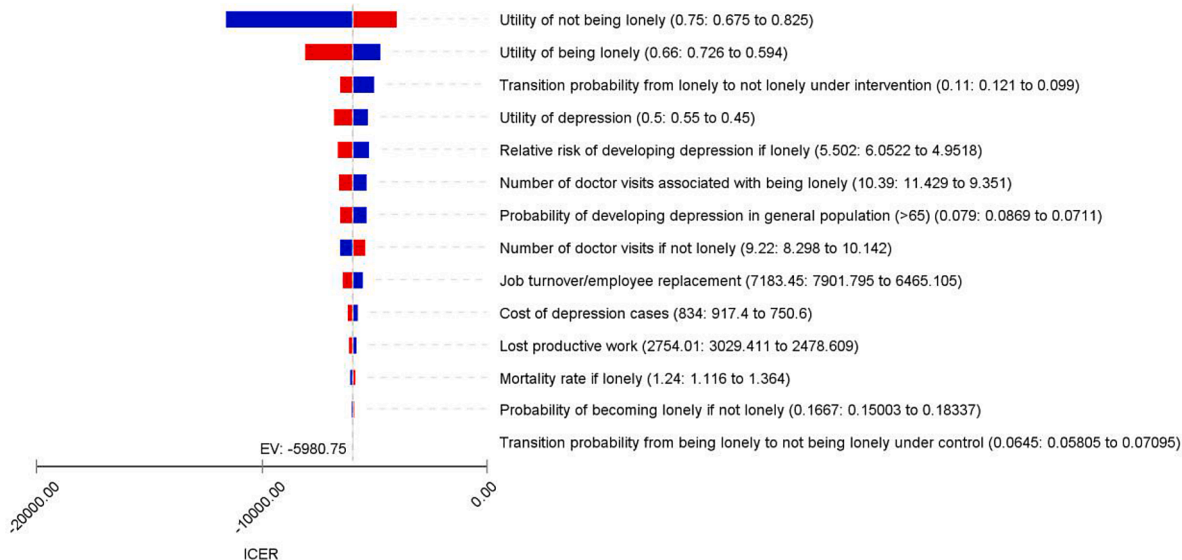
Where: $QALY_{lonely}$ is the total QALYs associated with being lonely; N_{lonely} is the number of older adults who are lonely; UW_{lonely} is the utility weight for being lonely; $P_{depressed \mid lonely}$ is the conditional probability of developing depression if lonely; $QALY_{not\ lonely}$ is the total QALYs associated with being not lonely; $N_{not\ lonely}$ is the number of older adults who are not lonely; $UW_{not\ lonely}$ is the utility weight for being not lonely; $P_{depressed \mid not\ lonely}$ is the conditional probability of developing depression if not lonely.

Appendix 7. Scenarios modelled in sensitivity analyses

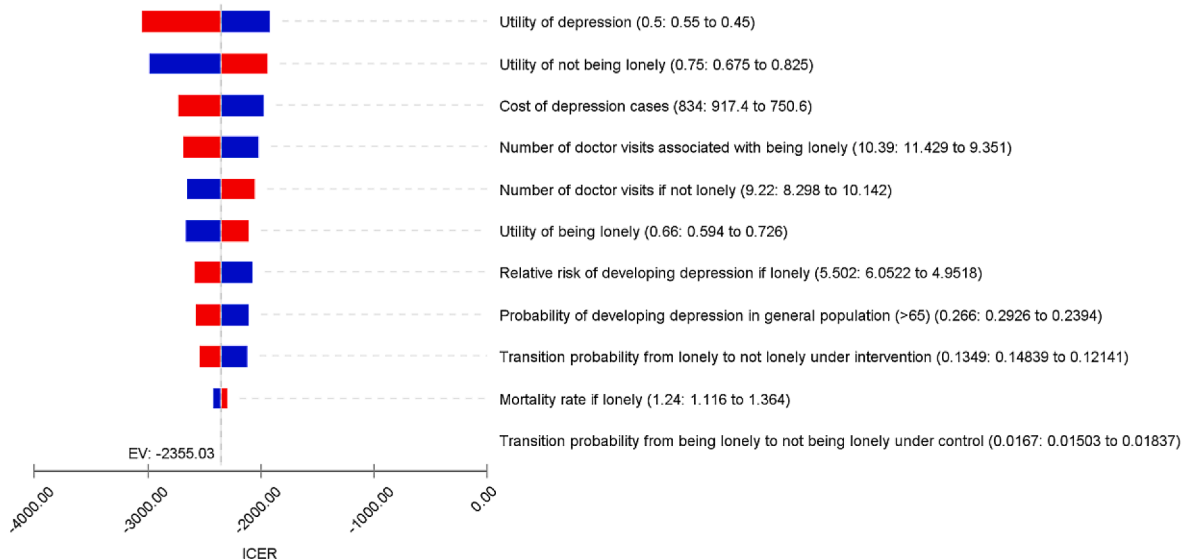| Scenario	Assumptions
Friendship Enrichment Programme (FEP)	
(SA1) Time and travel costs of women participating in the FEP	This scenario considered the time and travel costs of women participating in the 12 lessons and the final review meeting. In addition, the FEP also contains weekly homework tasks and it was assumed that for each of the 12 lessons, there will be 2-hours of homework required. The leisure time of older women was coasted at 25% of the hourly wage rate of people aged 55 and above ($9 per hour) (Australian Bureau of Statistics, 2017b). It was assumed that those women who are still engaged in work, would participate in the intervention outside their normal working hours and so productivity losses were not considered. In terms of travel cost, a unit cost of $8.62 was used for a round-trip per session (Vos et al., 2010).
(SA2) Excluding advertisement cost from the intervention cost	This scenario explored the cost-effectiveness of the intervention when advertising costs were not considered, assuming that the identification of lonely older women would occur through other pathways. For example, lonely older women aged 65 and above could be identified by the Aged Care Assessment team (ACAT).
(SA3) Increase in the number of social workers undergoing training	While the base case scenario assumed that each social worker would deliver the intervention to three groups, this scenario assumed that 1/3 more social workers will be required to deliver the intervention to groups comprising of 10 women per group.
(SA4) Intervention effectiveness	The incremental effect size of the intervention was reduced by 50%, which corresponds to a decrease in loneliness from 11% to 8.73% compared with 6.45% in the control group.
(SA5) Delivery of the intervention by a welfare recreation and community arts worker	This scenario assumed that the intervention will be delivered by a welfare recreation and community arts worker rather than a social worker whose salary is higher. Welfare recreation and community arts workers design and implement programs to meet the community and individual needs and assist individuals, families and groups with social, emotional and financial difficulties by educating and supporting them. The weekly cash earning of a welfare recreation and community arts worker (2726) were estimated at $34.84($26.80 per hour +30% oncosts) (Australian Bureau of Statistics, 2017b).
(SA6) 1 in 5 lonely women attending the session with someone else	This scenario assumed that 1 in 5 lonely women who find out about the program ask other lonely women to join the session. Three scenarios where modelled with respect to the expected benefits to those additional participants, with a 0%, 50% and equal benefit impact on the other person attending the session. Furthermore, it was assumed that these other participants would attend the session outside the potential work employment or other work commitments, i.e., no lost earnings from participating. The number of social workers required to deliver the intervention remained the same, meaning that only an increase in the group size was modelled.
(SA7) Excluding productivity impacts	This scenario excluded the productivity impacts of older women engaged in the work force.
(SA8) 3-year time horizon	This scenario modelled the cost-effectiveness over a 3-year time horizon
Volunteer-led internet and computer training (VICT)	
(SA1) Including the internet cost	This scenario considered the internet cost as part of the intervention for those receiving 1:1 home visits, assuming a broadband plan of $32.76 per month (or $393.06 per year). Internet service for those receiving visits in residential care facilities was still assumed to be already available.
(SA2) Changing the intervention effectiveness	This scenario used the effect size from the meta-analysis conducted across five studies (Choi et al., 2012). Although the interventions included in this meta-analysis were not all volunteer-led, they involved Internet and computer training that was provided to older adults living in the community or residential care. The meta-analysis found that the overall mean weighted effect size was statistically significant for decreased loneliness (Z = 2.085, p = 0.037). The Hedges'g effect size (g = 0.55, 95% CI: 0.03 - 1.06) was converted into RR using established Cochrane methods. This produced an RR of 2.68. The revised probability for moving from the 'lonely' to the 'not lonely' health state in the intervention scenario changed from 13.5% in the base case to 4.4% in SA2. The corresponding probability in the 'no intervention' scenario was again assumed to be 1.7%
(SA8) 3-year time horizon	This scenario modelled the cost-effectiveness over a 3-year time horizon

Appendix 8. Tornado diagrams

(A) FEP

(A) VICT

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