AGED AND COMMUNITY SECTOR TECHNOLOGY AND INNOVATIVE PRACTICE

A REPORT ON WHAT THE RESEARCH AND EVIDENCE IS INDICATING

UPDATE FROM THE ORIGINAL ACIITC LITERATURE REVIEW THAT INFORMED THE DESIGN OF THE TECHNOLOGY ROADMAP FOR THE AGED CARE SECTOR

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ACSA
Aged & Community Services Australia

LASA
LEADING AGE SERVICES AUSTRALIA
The voice of aged care

FOREWORD

We are living in a new era for the delivery of Aged and Community Services.

Given the speed of the technological change, this area is unprecedented and there are opportunities for the Aged and Community Care sector to embrace new technologies which are of essential importance.

This new research agenda for the Aged Care Industry Information Technology Council (ACIITC) details the opportunities that evidence is showing from research and the impact of new technologies on the delivery of care, services and business structure.

This activity of the ACIITC builds on the previous work we have undertaken in research and developing of Australia's first *Technology Roadmap for Aged Care* and it accompanies the first literature review (focused on the period 2011 – 2016). This research spans the period from this previous research (2016 – 2019) and is building a body of research around the impact of Innovation and Technology on the sector.

I trust you will find this important research activity essential reading and impactful when considering strategic direction for your organisation.

The ACIITC continues to work to provide the industry with a vehicle to consider and debate Innovation and Technology related opportunities and to disseminate the lessons learned from that progress to the wider Aged and Community Care industry. We strive to improve the quality of care providers through supporting and educating Aged and Community Care service providers about the efficiencies and service improvement capabilities that well managed Innovation and Technology system deployment can achieve.

Dr George Margelis

Chair

Aged Care Industry Information Technology Council

18 December 2019

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1. INTRODUCTION

THE ACIITC

The Aged Care Industry IT Council (ACIITC) was formed in 2007 by the two industry peak bodies - Aged and Community Services Australia (ACSA)and the Aged Care Association of Australia (ACAA) now Leading Aged Services Australia (LASA). The Council was designed to provide the sector with a vehicle to consider and debate Technology and Innovation-related opportunities and to disseminate the lessons learned from that process to the wider aged care industry.

1.1 CONTEXT AND METHODOLOGY FOR THE LITERATURE REVIEW

In 2016, the Aged Care Industry IT Council (ACIITC) commissioned Australia's first *Technology Roadmap for Aged Care*[1] which was published the following year. The Roadmap was informed by consultation with the aged care sector and with organisations providing technology to the sector, as well as by a review of the literature (Barnett, Reynolds, Gordon, Hobbs, Maeder et al 2017).[2] Its development was managed by the Chairs of the three ACIITC Committees. [3]

Given the speed of technological change, the Council has commissioned an updated review. This 2019, ***Aged and Community Sector Technology and Innovative Practice – A Report on what the Research and Evidence is indicating Report*** is based on a search of major research databases and of the grey literature, focusing on the period **2016-2019**, updating the first review that identified research studies published **2011-2016.** As with the first literature review, the search has focused on systematic and meta-reviews of academic research in order to bring together multiple publications which have been screened for methodological soundness.

Due to the lag between gathering and publishing research evidence, and the speed with which new technologies are developed, many of those innovations have not yet been assessed by researchers or had findings about their effectiveness published in the academic literature. However, the grey literature does provide information about them and indicators

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[1] ACIITC (2017) *Technology Roadmap for Aged Care in Australia,* Aged Care Industry Information Technology Council. Available at http://ACIITC.com.au/roadmap/

[2] The first literature review and the *Technology Roadmap for Aged Care* were developed by a team from the Flinders University Medical Device Research Institute led by Professor Karen Reynolds, with Dr Kate Barnett from *Stand Out Report* as the Lead Writer. Other team members were Professor Sue Gordon, Dr David Hobbs and Professor Anthony Maeder from Flinders University.

[3] **Technology Roadmap Management Team:** Ms Anne Livingstone, Chair ACIITC National Home Care Committee; Mr Gavin Tomlins, Chair ACIITC CIO Forum; Mr Rod Young, Chair ACIITC ITAC Committee

of their likely use and application. This Introduction to the 2019 literature review overviews some of the most disruptive of those technologies.

Findings from the literature review are presented in two main categories:

- Technologies that support positive ageing- see Section 2.
- Technologies that support the care of older people – see Section 3 (noting that some of the findings identified in Section 2 are also relevant to the provision of care).

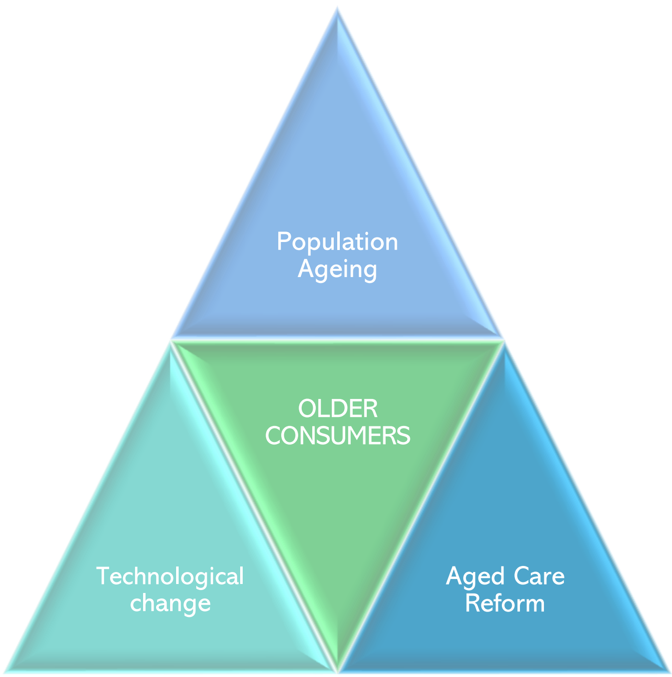
1.1.1. Drivers for a Technology Roadmap for Aged Care

The *Technology Roadmap for Aged Care* in Australia acknowledged the challenges and opportunities for the aged care sector arising from three intersecting meta-influences –

1) population ageing that has never been experienced to the same level as now
2) the rapid development of new technologies and
3) reform in the aged care sector that fundamentally changes the way in which older Australians are supported.

Central to all three is the consumer. These three influences continue to be significant.

FIGURE 1: META INFLUENCES SHAPING THE TECHNOLOGY ROADMAP FOR AGED CARE

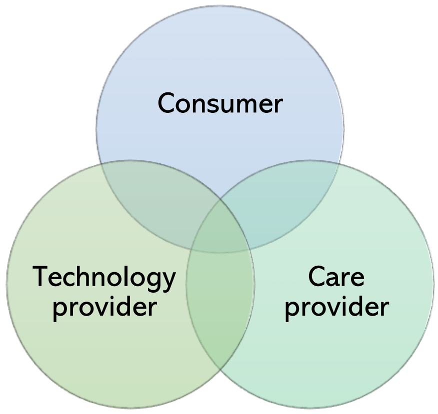


1.1.2. Intersecting transformative change: the growing significance of partnerships

As technology has evolved (see Section 1.2) a new intersection is emerging that is reshaping who delivers health and aged care, and how this care is delivered. In addition to health and aged care service providers, technology providers (developers and vendors) are now key players, most effectively when they work in **collaboration** or formal **partnerships** with health and aged care providers. Many technologies are invented without the purpose of providing care or support to older people, but have that outcome and are, therefore, relevant (eg Smart

Homes, voice-activated technology). In addition, consumers are increasingly part of a collaborative delivery process because of their increased ability (through technology) to monitor their health status and share findings with their care providers, and therefore, to self-manage some of their care and support. Again, this is most effective if it is based on a *partnership of care* to ensure that the technology involved is appropriate, and if that technology has been co-designed with end-users. For the first time, each of these three stakeholder groups has become a co-provider and a co-supporter.

FIGURE 2: A NEW PARTNERSHIP OF CARE PROVISION



As part of this process, new providers have entered the care 'market', for example, Apple and Google (see Case Study 1, Section 2.2.3). In 2014 Apple developed, with input from the Mayo Clinic, the *HealthKit*[4], designed to fit into health and fitness apps in order to track and generate health and activity data. The Apple-Mayo Clinic partnership brings a range of benefits for both[5] organisations but exemplifies the disruption occurring in the care sector as a range of new (non-care) providers become part of the delivery landscape. The *GoogleFit* platform also organises data from multiple health-focused apps and it too has developed partnerships with health providers. Google's presence in the healthcare field has grown significantly and can be expected to continue to do so as new technologies, particularly Artificial Intelligence, play an increasingly important role.[6]

The recent entry of Ikea into the ageing-related market is also indicative of this disruption. *Boklok* is a company co-owned by and Swedish construction firm Skanska. In 2015 they began the *Silviabo* Project which is backed by Queen Silvia of Sweden, its namesake. *Boklok* are developing affordable, flat-pack *Silviabo* homes for people living with dementia, drawing on the evidence base for the dementia-friendly design. [7]

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[4] https://developer.apple.com/healthkit/

[5] https://www.forbes.com/sites/dandiamond/2014/09/09/iphone-6-apple-and-mayo-clinic-partnership-could-be-smart-medicine-2/#47f2b38974e6

[6] https://www.cbinsights.com/research/report/google-strategy-healthcare/

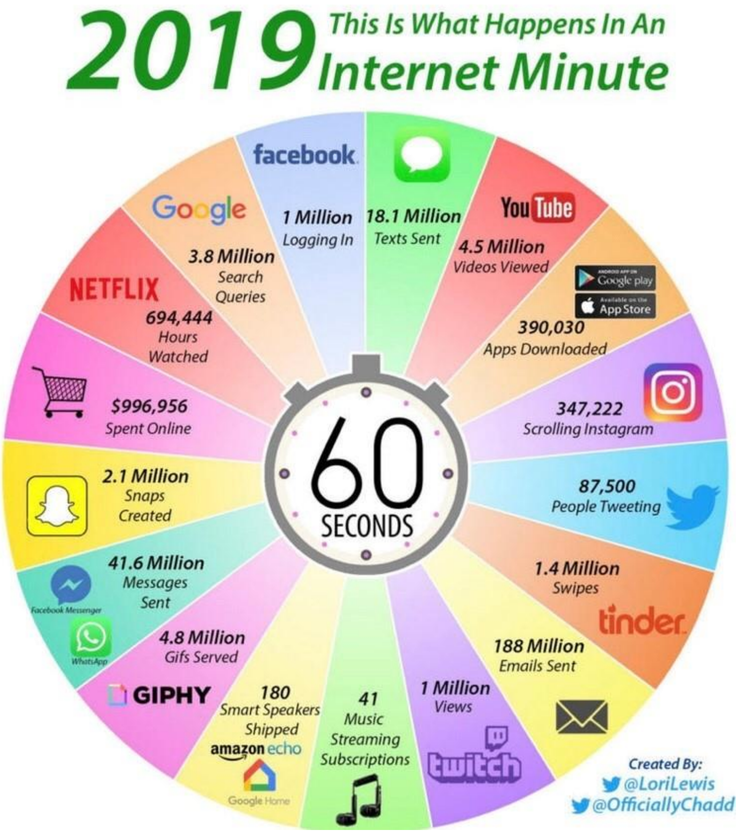
[7] https://www.designboom.com/design/ikea-homes-people-with-dementia-08-09-2019/

The intersection of an ageing population with technological progress has produced the term *Geotechnology* which emerged in the early 1990s[8] to describe a new interdisciplinary academic and professional field combining gerontology and technology.

Advances in communication technologies, devices connected to the internet and data analytics are occurring at a much quicker pace than at any other time in history. As a result, many believe we are now living through a fourth industrial revolution, referred to as 'industry 4.0' (i4.0).

> ***Industry 4.0 refers to the current point of rapid technological change that is disrupting how businesses conduct their operations across all industries (RMIT Digital Enterprise Centre: 2019).[9]***

The diagram below illustrates the magnitude of our Internet-based lives, showing human interactions on a number of platforms in the space of a minute.



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[8] Bouma H & Graafmans J (1992) *Gerontology,* IOS Press, Amsterdam

[9] https://www.rmit.edu.au/industry/develop-your-workforce/tailored-workforce-solutions/c4de/industry-40

The major difference between industry 4.0 and the industrial revolutions that came before is that technology is something that is **embedded** into every aspect of our lives (RMIT Digital Enterprise Centre: 2019).[10] Increasingly, this will be the case for aged care, with technology being less of an after-thought and central to business operations as well as care provision. The changes overviewed in the next section give an indication of that future.

1.2 AN OVERVIEW OF KEY RECENT TECHNOLOGICAL CHANGE

Technological innovation isn't a straight line. It's not like a skyscraper with one floor of scientific achievement built vertically on top of another. Innovation is better represented as an inverted pyramid where one idea leads to several more which support yet more ideas (Hajkowicz & Dawson 2018: 10).

In recent years, and particularly since the ACIITC's initial literature review in 2016, there have been significant advances made in a number of technologies that hold promise for enhancing the lives of older people as well as their formal care. The research evidence base is still building in relation to these technologies, but an overview is provided here because of their potential. *While they are discussed separately, it is important to remember that they are also being used in combination with significant effect.* As one technology advances, it affects the development of others, with Artificial Intelligence (AI) being a common denominator. For example:

- falls technology (discussed in Section 2.4.1) has evolved from detection to prediction (and therefore, prevention) status because of the combination of sensor technology and artificial intelligence.
- AI-based data analytics can be applied to predict likely health events, including hospital admissions.
- AI-enhanced software can be harnessed to improve care providers' performance and quality outcomes, enabling an automated compliance system (aligned to industry standards) but also linked to planned consumer outcomes.
- The combination of AI and Blockchain is transforming information exchange, supporting cross-sector data sharing while addressing concerns about security and control of data.
- The ongoing evolution of the Internet of Things and the integration of smart devices into everyday living is being accelerated as AI and Blockchain combine to determine how these different devices communicate and interact.

[10] https://www.rmit.edu.au/industry/develop-your-workforce/tailored-workforce-solutions/c4de/industry-40

1.2.1 Advances in Artificial Intelligence and Automation

Artificial intelligence isn't a single system nor a single technological breakthrough. It's what happens at the convergence of multiple technologies and multiple fields of scientific research. Today's building blocks for tomorrow's artificial intelligence are more powerful, and more diverse, than ever before in history. This creates a future world with vast potential for transformative artificial intelligence technologies (Hajkowicz & Dawson 2018: 10).

Artificial Intelligence (AI) increasingly forms part of everyday reality as it is applied as part of technologies that make life easier, but increasingly, as a key component of technologies that support health and aged care provision. It is the *combination* of AI with specific technologies that are significant for the aged care sector.

In artificial intelligence (AI), machines are programmed to develop cognitive functions for learning and problem-solving. AI has the potential to augment human intelligence just as machines increased physical capabilities a century ago (World Economic Forum 2018: 2 7).

Advances in machine learning, in particular, in *deep learning* which replicates the structure and function of the human brain, meaning that machines now can learn and solve complex problems without human guidance. For example, Google scientists recently developed *AutoML* - an artificial intelligence software tool that codes its own artificial intelligence.

The ability of AI to automatically analyse huge amounts of data holds significant potential for the health and aged care sectors, not only in care provision but also in achieving business efficiencies by reducing errors and streamlining processes (see the *CSIRO Data61 and Commonwealth Bank* collaborative initiative below in Section 1.2.2). The CSIRO's Data61 team predict significant advances in AI generally, and in particular, in sensory systems, machine learning and predictive analytics (Hajkowicz & Dawson 2018: 9).

1.2.2 Advances in Blockchain and Data Analytics

Blockchain is defined as a distributed, decentralized data ledger but can be simply described as a shared database. The technology enables the creation of digital records and their sharing and management securely on a network. Each participant has an identical copy of the database, which is updated as changes are made in real-time (World Economic Forum 2018: 32).[11]

A significant feature of Blockchain is its capacity to exchange information without the need for an intermediary and became well known because of its use in cryptocurrencies. Applying the technology to healthcare is expected to 'revolutionise" the sharing and management of health (and aged care) records because of its ability to document, exchange (with multiple

[11] World Economic Forum (2018) *These are the top 10 emerging technologies of 2018.* https://www.weforum.org/agenda/2018/09/top-10-emerging-technologies-of-2018/

stakeholders) and track data while safeguarding security and control of the data by its owner. For this reason, Blockchain's capacity to provide a transparent data trail is seen by some experts as having the potential to overcome interoperability challenges currently limiting data exchange (Rupasinghe et al 2019; World Economic Forum 2018). As with all technologies, it does require accompanying standards and ethical guidelines to safeguard privacy and data protection.

> *The need for data analysis and informatics will continue to dramatically expand as the digital revolution changes the ways people make decisions and the very ways in which people live their lives (Hajkowicz & Dawson 2018: 17).*

AI is playing an increasingly critical role in analysing the huge volumes of digital data generated in multiple sectors, including health and aged care, that are too dense for traditional data processing tools. Some of that information involves digitised health records but some also originates from new technologies, particularly sensor devices that monitor patterns of behaviour. When triangulated with more traditional data sources this can provide powerful analytical and predictive capabilities for healthcare providers and policymakers, improving decision-making and addressing inefficiencies in the healthcare ecosystem (Hajkowicz & Dawson 2018).

Please refer to Destination 1: Technology-enabled operational, business and communication systems of the *Technology Roadmap for Aged Care* for a discussion of the need for interoperability, open standards and common platforms to support digital data sharing within the aged care sector and with other sectors, particularly health.

CSIRO DATA61 AND COMMONWEALTH BANK: TRIALLING BLOCKCHAIN-POWERED SMART MONEY

In 2018, a partnership between CSIRO's Data61 and the Commonwealth Bank (CBA) successfully trialled a new type of Smart (or programmed)[12] money, powered by Blockchain, with the NDIS as the first proof of concept case study. The trial demonstrated that Smart money could be used to help budgeting and the management of trusts and charities in Australia, as well as to manage insurance payouts, while also benefitting NDIS participants.

Enabled by a prototype App, the system enabled participants to manage their plan, to locate, book and pay for services from NDIS service providers without the need for paperwork or receipts and the time and effort involved by paper-based procedures. It was tested with 10 NDIS

[12] 'Smart' or 'programmable' money allows for conditions to be attached to payments to allow tracking of who spent what, where and to identify merchants (https://www.itnews.com.au/news/cba-data61-build-prototype-app-for-blockchain-based-ndis-payments-513682)

participants and carers in the CommBank Innovation Lab as well as a small number of medium-sized disability service providers.

Among the benefits identified for participants were greater choice and control over their disability support services, while the NDIS benefitted from reduced administration costs and paperwork as well as from reduced fraud risk and accidental misspending. Participants and carers estimated that the prototype App could save them between one and 15 hours per week, while service providers estimated potential annual cost savings as a percentage of revenue of 0.3 per cent to 0.8 per cent.

CBA modelling highlighted significant potential for the entire NDIS ecosystem with a conservative estimate of savings of hundreds of millions of dollars annually if the proof of concept was implemented as part of a full-scale solution across Australia. Those benefits could have application across the aged care system.

See: data61.csiro.au/smartmoney

MANAGING ALGORITHM BIAS AND VALIDATION

The grey literature identifies two areas of concern in relation to the algorithms that drive AI. One of these relates to their validation and the other to their susceptibility to subjectivity and bias.

Best practice requires that an AI algorithm must be validated on external datasets from multiple institutions before being applied on a wide scale. However, recent research that analysed 516 published studies of AI algorithms designed to support diagnostic analysis of medical images found that only six per cent (31 studies) externally validated their AI and none of those determined whether their algorithms were ready for clinical use. Instead they were designed as proof of concept technical feasibility studies that lacked the robust validation of real-world clinical performance assessment (Kim et al 2019). This is a criticism that could be applied to much of the 'research' associated with new technologies – their focus is on technical feasibility (i.e. if they work or not) without determining their effectiveness for individuals who will be affected by them.

Algorithms are written in the first instance by humans and cannot be guaranteed to be bias-free. This is a significant concern for AI-driven technologies designed for older people, with widespread ageism likely to shape algorithms.

> ***… as big data and analytics and AI become more pervasive in healthcare, we need to guard against bias. There is a widespread belief that software and algorithms that rely on data are objective. But software is not free of human influence. Algorithms are written and maintained by people, and machine-learning algorithms adjust what they do based on people's behaviour. As a result, researchers in computer science, ethics and law have noted that algorithms can reinforce human prejudices (World Economic Forum 2018: 35).***

1.2.3 Continued evolution of sensor technologies

Apart from sensors which are installed in specific environments, the development of *wearable* devices that achieve similar outcomes has created significant scope for those able to move independently outside of the home. These devices are portable but connected and can be tailored to individual need and preference. Key enablers for their development include the widespread use of Smartphones (especially in Australia), longer-lasting batteries, and new materials and fabrics (including smart clothing, textiles and jewellery). AI-enabled sensors are allowing the collection of information about individual patterns of behaviour in real-time, enhancing assessment but also supporting the prediction of outcomes, which in turn, enables early intervention and prevention by health and aged care providers.

The evolution of sensors has been boosted by developments in nanotechnology that enable the development of *implantable or injectable sensors* that can be placed in the human body, and like wearables, support personalised treatment. Bioelectric implants — also known as *electroceuticals* — are minute devices that are attached to a nerve to read and modulate electrical signals generated by the body's nervous system. These devices offer the potential for targeted treatments because they affect a specific organ and avoid the side effects commonly associated with traditional medicine formats and injectable drugs.

> ***Interventions that speak the electrical language of the body will become central treatments in a host of major chronic diseases such as diabetes, asthma, hypertension, arthritis, pain and possibly even cancer (British pharmaceutical firm GlaxoSmithKline website).***[13]

Nanotechnology also makes possible the printing of sensors with very fine features onto flexible rolls of plastic, in large quantities, at low cost. Recent advances in nano 3D printing (which uses a laser to print objects as small as 100 nanometres– about 1000 times thinner than a human hair) enable the printing of large objects by joining nano-size objects together. This has seen the production of lab-grown retinas, new bones and nano-robots designed to deliver precise chemotherapy, highlighting substantial promise for future health care.[14] More than 1,700 consumer products containing nanoparticles have been introduced into the marketplace since 2005 (World Economic Forum 2018: 25).

Changing the structure of materials through nanotechnology holds a range of possibilities, for example, creating water-repelling textures, adding coatings that allow materials to repair when damaged and creating textiles that can regulate temperature. Such developments have significant potential in the support and care of older people.

1.2.4 Ongoing development of Virtual Reality and Augmented Reality

> ***Virtual reality (VR) is an artificial, computer-generated simulation or recreation of a real-life environment or situation. Augmented reality (AR) is a technology that layers computer-generated enhancements on top of an existing***

[13] http://www.meddeviceonline.com/doc/gsk-sets-trials-for-electroceuticals-for-chronic-diseases-0001

[14] Liam Mannix (2019) *Nano-scale printing promises lab-grown retinas, custom-made bones,* The Age, 30/3/19 https://www.theage.com.au/national/nano-scale-printing-promises-lab-grown-retinas-custom-made-bones-20190329-p518tn.html

reality to make it more meaningful through the ability to interact with it (World Economic Forum 2018: 32).

One of the sectors where Virtual Reality (VR) is most effective is in serving as a scalable alternative to traditional training methods, which otherwise require face to face, personally delivered programs to have the best learning outcomes (Bozorgzadeh 2019). There are a growing number of VR supports to the provision of dementia care, enhancing provider (and carer) understanding by replicating the dementia experience (see Section 3.6.3, and Case Study 4) and more recently some enabling early identification of dementia through sensors and through the use of machine learning (see Section 3.6.4).

A scoping review of current research regarding Augmented Reality (AR)[15] in nursing identified 23 publications of which 16 included evaluations of their application in nursing (noting that the majority describe *pilot* studies only). Most of the studies used a Smart Glass, but some used a Smart Watch, a Head Mounted Display, a Helmet Mounted Display, a Smartphone or a tablet. Technical challenges were identified during the use of each device. This review found that while the number of empirical studies was relatively small, there has been a trend for recent growth - for example, only five of the 23 studies were published before 2015 (Wuller et al 2019).

Section 3.6 explores the application of VR technology for supporting people living with dementia.

1.2.5 Voice-activated technology

Voice-activated technology has become key to smart home connected devices, providing virtual assistants for a range of daily tasks. Voice recognition technology can include converting voice to text (see below), setting up reminders (eg to take medication), searching the internet, and responding to simple questions and requests, such as playing music or sharing weather or traffic information. Combined with artificial intelligence this is becoming a powerful tool making the use of technology easier but also requiring interventions to protect individual privacy. It also has significant potential in supporting independent living and access to aged care services, as illustrated in Case Study 1 in Section 2.2.3.

Apple, Amazon and Google and have been leaders in this field, with the Siri, Alexa and Google Home voice assistants. These are all evolving and broadening their application. For example, Microsoft, Google and Amazon are three of several firms developing technologies designed to determine emotional states from inputs that include images and audio data. Amazon's Alexa software now offers a HIPAA-compliant[16] Skills Kit that allows medical organisations to build Alexa skills capable of transferring and receiving protected health information. As part

[15] That is, the enhancement of reality with virtual content

[16] The Health Insurance Portability and Accountability Act (HIPAA), passed by the U.S. Congress in 1996, is designed to make health-related information easier to share between providers. It encourages the use of electronic medical records, while providing security and privacy standards for handling Protected Health Information

of that initiative, Amazon collaborated with six healthcare companies to create the six new skills that were recently launched. [17]

Amazon's recent partnership with the UK's National Health Service (NHS) is using Alexa to enable people to access verified health information. It is possible to ask Alexa questions about symptoms or treatments and obtain (algorithm-driven) verified advice without leaving home. The NHS hopes to relieve demand on general practitioners and hospital emergency services by providing access to information that some people are unable to reach through digital channels.[18]

VOICE TO TEXT

Voice to text technology has significant potential for health service providers burdened by the time taken to enter information for electronic health records. AI-driven voice to text technologies record and transcribe conversations between health providers and consumers, transferring them directly to electronic records. This can reduce transcription errors[19] and in combination with smart clinical devices (i.e. that automatically record readings) has the potential to enhance efficiencies and enable providers to spend more time interacting with consumers.[20]

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[17] Hedges L (2019) Are Patients Ready for Amazon Alexa, MD? *Software Advice,* August 9, 2019. Accessed at: https://www.softwareadvice.com/resources/alexa-healthcare-skills/

https://www.theage.com.au/business/companies/amazon-is-working-on-a-device-that-can-read-your-emotions-20190524-p51qpi.html

[18] https://www.digitalhealth.net/2019/07/nhs-partners-amazon-alexa-health-advice/

[19] At this stage, human checks are still required because transcription errors have not yet been eliminated.

[20] Meskó B (2019) Voice to Text Technologies Shape the Future of Electronic Medical Records, *Medical Futurist Newsletter,* September 12th 2019 - https://medicalfuturist.com/voice-to-text-technologies-shape-the-future/

2 TECHNOLOGIES THAT SUPPORT POSITIVE AGEING AND INDEPENDENT LIVING

2.1 OVERVIEW: TECHNOLOGIES THAT ASSIST DAILY LIVING

2.1.1 Defining terms

Traditionally aids to daily living were not technology-enabled (for example, walking sticks, adapted utensils, etc) and were limited in the amount of independence they could provide. However, advances in technology have brought the evolution of what are known collectively as *'Assistive Technologies'* (ATs). The World Health organisation has defined Assistive Technology as:

> ***An umbrella term for any device or system that allows individuals to perform tasks they would otherwise be unable to do or increases the ease and safety with which tasks can be performed* (Glossary of Terms for Community Health Care and Services for Older Persons, 2004*).***

A further level of sophistication is becoming increasingly evident with the addition to ATs of artificial intelligence and automation capacity, and those that bring their own computational ability and can share information across networks are often referred to as *Intelligent Assistive Technologies (IATs)*.

> ***IATs are assistive technologies with [their] own computation capability and the ability to communicate information through a network …. IAT encompasses a wide spectrum of technological applications currently used or in-development …. These include self-contained devices (e.g., tablets, wearables, personal care robots, etc.) and distributed systems (e.g., smart homes, integrated sensor systems, mobile platforms, etc.), as well as software applications (e.g., mobile or web-based apps) (Ienca et al 2017: 1302).***

Taking a broader view, the evolution of *Technology-Enabled Care (TEC)* that supports the provision of health and aged care services has seen this umbrella term emerge to encompass telecare, telehealth, telemedicine, mHealth, eHealth and digital health (Deloitte 2015). These terms are defined in Section 2.3.1.

> ***TEC involves the convergence of health technology, digital, media and mobile telecommunications and is increasingly seen as an integral part of the solution to many of the challenges facing the health, social care and wellness sectors, especially in enabling more effective integration of care (Deloitte 2015: 1).***

2.1.2 The growing importance of Apps and Smartphones

Apple launched the iPhone in 2007 and opened its App Store in 2008, quickly followed by other competitors in this disruptive and still growing market. Smartphones and Apps are inextricably linked in their growth and their impact on everyday lives, as well as on businesses.

> ***This unexpected "side-effect" of the smartphone quickly took on a life of its own, creating a whole new class of iOS and Android developers who were***

writing mobile applications that could run on smartphones anywhere. It's not an exaggeration to speak of a global App Economy, with an army of app developers writing mobile applications for billions of users. For businesses, apps have become the essential front door for their customer .... What's more, the App Economy still has room to grow (Mandel & Long 2019: 2).

Analysis of government occupational statistics and data on posted job openings by the Progressive Policy Institute has yielded an estimate of 136,000 App Economy jobs in Australia as of January 2019, up from 113,000 in March 2017 – a *20 per cent gain* in the last two years (Mandel & Long 2019: 3).

Apps have quickly become an integral part of everyday living for many people and are now a key part of accessing government services. Not only do Apps have a role to play in providing services, but the data generated through their use offers significant secondary benefits by providing reliable and real-time data on patterns of service use, needs and preferences. (This is exemplified in Case Study 4: Sea Quest which is presented in Section 3.6.3).This can drive service reform, design and modify services that are responsive to consumer preferences and achieve a range of efficiencies (assuming they are designed appropriately and with user ease in mind).

Smartphone ownership in Australia has been increasingly steadily. Deloitte's 2018 *Mobile Consumer Survey* found that 89% of 2,000 Australians surveyed owned a smartphone, a slow increase from 84% in 2016 and 88% in 2017, and is considered to have reached a point of saturation in 2018.[21] This is higher than ownership of laptops and makes the Smartphone central to providing older Australians with access to a range of technologies designed to support independent living.

Importantly, the evolution of the Smartphone has seen them include technologies such as sensors (accelerometer, gyroscope, GPS), that can generate data obtained in 'real-time', which if linked to appropriately designed Apps, not only provides feedback to the individual about their health-related status but can also be utilised by care providers. (See Section 3.2 which describes the role of Smartphone inbuilt technology in falls prevention and detection.)

The developing Smartphone and App economies, by originating outside of the care provision environment, are *normalising* health promotion and support technologies, avoiding the stigmatisation associated with many Assistive Technologies. This is critical for their adoption by older people, and also makes them highly accessible.

[21] Deloitte (2018) Mobile consumer survey. https://www2.deloitte.com/au/mobile-consumer-survey

2.1.3 Overview of key technologies supporting independent living for older people

The research literature provides a growing evidence base for the effectiveness of certain technologies in relation to a number of service types but also in targeting specific needs – highlighting its relevance for enhancing independent living – with or without aged care services.

A major systematic review of the literature published from 2000-2015 (unfortunately not updated since then) began with an initial set of 2,035 studies focusing on studies of people aged 60 and over that applied technologies to key ageing issues and provided empirical evidence of the impact of these on each issue. Most of the 41 studies included in the final group employed randomized controlled trial or quasi-experimental methodologies (Khosravi and Ghapanchi 2016). They categorised technology as having been confirmed to play a role in the following:

- Promoting independent living (mainly through monitoring technology).
- Improving medication management.
- Reducing social isolation and increasing social connection.
- Identifying and managing falls, and more recently, predicting the risk of falling.
- Managing chronic disease (mainly through the telehealth and telecare technologies).
- Supporting people with cognitive issues, particularly dementia.
- Reducing or managing depression and enhancing well-being.
- Supporting family and other informal carers (Khosravi & Ghapanchi: 2016).

Since that review, these technologies have continued to be significant in supporting independent living and better quality of life, augmented by advances in other technologies that intensify their impact – particularly in relation to artificial intelligence and automation – and by improvements in specific technologies – for example, voice activation and robotics. Systematic reviews consistently identify home sensors as playing a critical role in regulating ambient temperature, operating household appliances, and security systems (Morris et al 2014: 14; Reeder et al 2013: 574) and providing an ideal environment for supporting a range of other technologies designed to address ageing-related challenges. Sensor technologies are evolving rapidly and are key to the accompanying growth of Smart Homes.

2.2 SMART HOMES SUPPORTING INDEPENDENT LIVING

The transformative impact of technology on everyday lives and living is particularly apparent in the developing 'Smart' living market. Smart home technology, also often referred to as *home automation* or *domotics*[22], embeds a range of largely digital technologies designed to produce greater automation, energy efficiencies, convenience, security and easier management of day to day activities. Smart Home systems and their linked devices and appliances operate as part of the Internet of Things (IoT)[23] and are controlled by a master home automation controller, often called a *Smart Home Hub*, that can be controlled remotely,

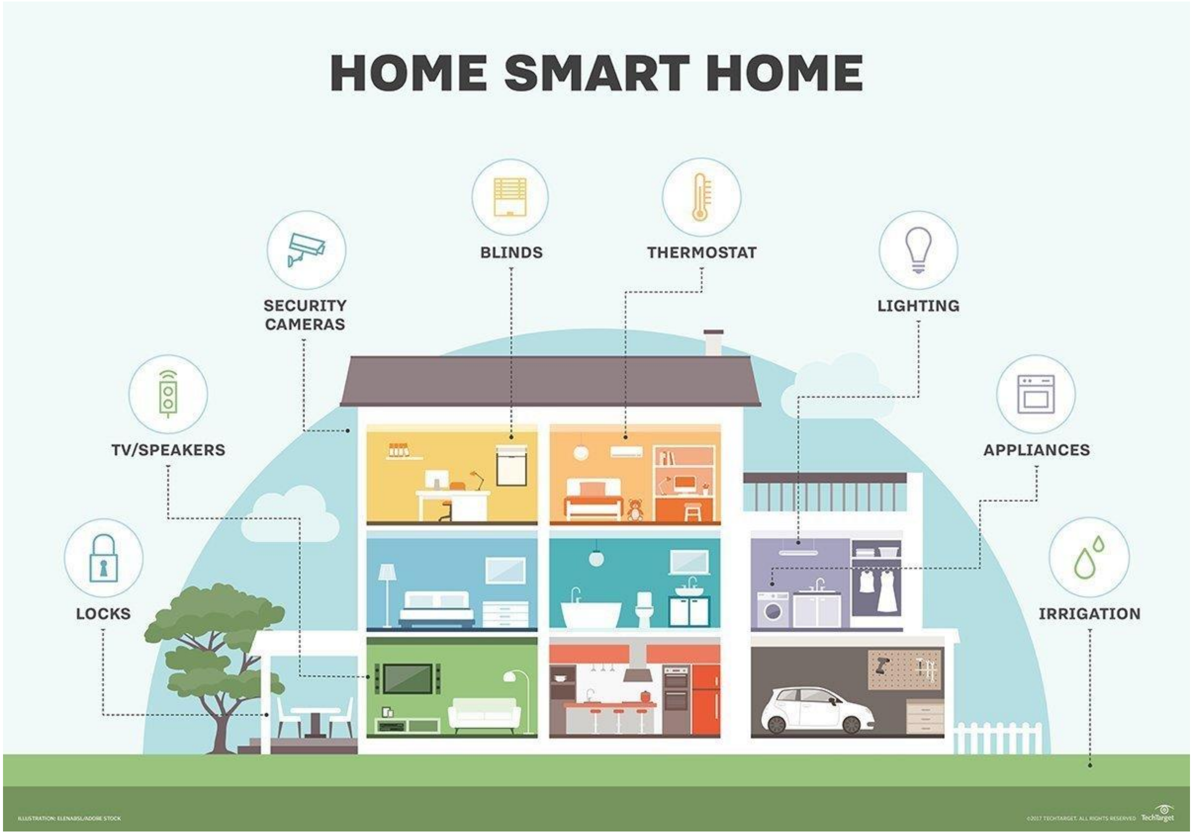
[22] from the Latin "domus" meaning home

[23] *The internet of things, or IoT, is a system of interrelated computing devices, mechanical and digital machines, objects … that are provided with unique identifiers … and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.* https://internetofthingsagenda.techtarget.com/definition/Internet-of-Things-IoT

usually by a Smartphone. *Amazon Echo* and *Google Home* are well-known examples of Smart Home Hubs.

Machine learning and artificial intelligence (AI) are increasing the sophistication of Smart Home technology, allowing home automation applications to personalise based on user preferences and patterns of behaviour. Recent advances in Voice Activation technology (see Section 2.2.2) make it possible to control smart home technology without also needing high levels of digital literacy – a significant advantage for many very old people. Voice Assistants like *Alexa* and *Google Home Assist* have a growing share of the Smart Home market, but also involve partnerships with care providers to tailor solutions for those needing support and care (see Section 2.2.3 Case Study 1).

FIGURE 3: ILLUSTRATION OF THE SMART HOME CONCEPT



Source: https://internetofthingsagenda.techtarget.com/definition/smart-home-or-building

As these technologies evolve, they highlight the critical importance of people's homes and local environments to their independence, and to healthy and positive ageing. As such, they can reduce the likelihood for many people of entering residential aged care as a result of functional decline and illness. However, these advantages need to be weighed against concerns related to security (when hackers can gain access) and data privacy (particularly in relation to Voice Assistants), and therefore, need to be accompanied by protection and security audits as part of the installation process.

SMART HOMES: A RAPIDLY EXPANDING MARKET

The Smart Home market continues to grow rapidly, Data from the latest ***Telsyte Australian IoT@Home Market Study 2019*** report[24] identifies the following trends:

- Expansion of the Australian Internet of Things at home (IoT@Home) market by 57 per cent in 12 months to reach $1.1 billion in 2018.
- More than 50 per cent of Australian households (5 million households) are consumers in this market - an increase of more than 30 per cent in 12 months that is attributed primarily to the adoption of smart speakers.
- In terms of revenue, the smart energy segment is now worth more than one-third of the total IoT@Home market – driven largely by the adoption of smart energy solutions.
- In the longer term, Smart connected appliances (e.g. white goods) are expected to represent some 40 per cent of the industry's annual revenue by 2023.
- At present, the IoT@Home market is being driven by younger age groups, particularly younger families and 'tech enthusiasts'.

Source: Telyste (2019) https://www.telsyte.com.au/announcements/2019/5/14/australian-iothome-market-cracks-1bn-paving-the-way-for-iot-commerce-services

There is a relatively small amount of robust research testing the effectiveness of Smart Home technologies to support older people to live independently, while the amount of essentially descriptive studies is large (Peek, Aartsa & Woutersa (2017 citing multiple studies; Morris et al 2014; Peetoom et al 2014; Reeder et al 2013; Calvaresi et al 2016; Brownsell et al 2011). For example, a recent systematic review designed to identify the influence of Smart Homes on older people's quality of life identified 4,512 publications relating to this issue of which only 31 met the review's inclusion criteria (Debaiyoti, Triyason & Funikul 2017). Similarly, another systematic review identified 1,877 publications of which only 21 studied effectiveness and only one involved a randomised controlled trial (Morris et al 2013).

There is a trend for studies to focus on technical issues without also exploring the extent to which smart living technologies meet the needs of end-users (Marikyan, Papagiannidis & Alamanos 2019; Calvaresi et al 2016). While the literature continues to grow, it has *followed* rather than led this technology sector driven field (Wilson, Hargreaves & Hauxwell-Baldwin 2013: 3).

[24] The 2019 report is the seventh in a series that uses a representative survey sample of 1,025 people aged 16 years and over. The survey process is supplemented with interviews with executives from service providers, network operators, manufacturers, retailers, financial analysts and channel partners, monitoring and analysis of local, global and vendor trends, and analysis of industrial reports and reviews.

2.2.1 What do older people want from Smart Homes and other technologies?

Research findings indicate that older people hold mainly positive attitudes towards the Smart Home concept, particularly because of its capacity to support independent, assisted living, health monitoring and enhanced quality of life. However, while they perceive the potential to increase their safety and security at home, they also express concerns (as do consumers of all ages) about privacy and data security issues (Debaiyoti, Triyason & Funikul 2017; Morris et al 2013). One systematic review found that older adults …

- expect to be active participants in the design and ongoing implementation of the smart home in which they will live;
- want to share decisions about when they are monitored and with whom to share monitoring data;
- have identified as useful bed sensors and gait monitors;
- regard camera and video monitoring of sensor-based results as raising privacy concerns - although it is accepted that videos play a role in detecting emergencies;
- want devices to be user-friendly, reliable, with low purchase and maintenance costs, and not intrusive;
- value the provision of training in how to use devices;
- are motivated to use smart technologies which address needs of independence and safety, and more broadly, which are perceived to be needed by them (Jacelon & Hanson 2013: 116-118; Morris et al 2013: 6).

A recent review of peer-reviewed journals identified 12,390 publications from which 14 studies were selected relating to the effectiveness and feasibility of *Health Smart Home* technologies in promoting autonomy and quality of life – as seen from the perspectives of older people using them (Nagapuri, Maeder & Williams 2019). (*Health Smart Homes* were defined as assisting in providing continuous health monitoring and supporting well-being for assisted living through digital technologies.)

The review found a greater focus by studies on the technical aspects of Health Smart Homes and a minimal focus on how best to meet the needs of older users. Nevertheless, the studies reviewed identified the need for co-design with end-users in all stages of Health Smart Home system design, implementation and testing, while the failure of a system was often linked with lack of communication and collaboration between users and technology developers (Nagapuri, Maeder & Williams 2019: 133-134).

2.2.2 A growing role for Voice Assistants

In recent years, the growing importance of voice activation technology has been evident in the popularity of 'digital assistants' or 'virtual assistants' – well-known examples being *Alexa* (made by Amazon) and *Google Home*. These take the form of 'speakers' that respond to a voice(s), which in turn activates commands. While research concerning virtual assistants is still in its infancy, these devices have great potential for older people (Mc Ardle, Morris & Hickey 2018).

This is exemplified with *My Carer Alexa* which supports people with early-stage dementia to set reminders for daily tasks, such as when to prepare meals or take medicines and can assist in recalling facts about family and friends,[25] Again highlighting the importance of partnerships between technology experts and aged care experts, it was developed through a partnership between the UK Alzheimer's Society, digital studio *Skilled* and the *McCann Worldgroup* marketing firm. Changes in speech patterns can indicate early-stage development of Alzheimer's Disease, creating the possibility of Digital Assistants playing a role in future diagnosis.

Zion Market Research recently estimated that the speech and voice recognition market will increase from a value of USD 6.19 billion in 2017 to USD $22.3 billion by 2024, with the addition of Artificial Intelligence augmenting its uses and impact https://www.zionmarketresearch.com/news/speech-and-voice-recognition-technologies-market.

Case Study 1 (below) illustrates the potential for voice-activated digital assistant technology to support independent living for older people. Voice activation overcomes the challenges faced by those who did not grow up in the digital age and who lack the skills associated with digital literacy as it does not require the use of a computer or tablet. This technology can compensate for challenges associated with dexterity issues, vision or memory that limit the ability to interact with computers or Smartphones.

2.2.3 Case Study 1: Feros Care using Voice Command Technology to support independent living

Feros Care has partnered with Google to integrate the *Google Assistant* voice-command platform into its home care services, enabling consumers to find information on their *MyFeros* Portal and interact with services. The Portal was implemented as a pilot in March 2018 and since then its uptake by consumers has been increasing. A key advantage of the Portal is that, at its most basic level, it provides an alternative to the phone-based Contact Centre. Two months after its introduction, calls to the Contact Centre had reduced by 85 per cent, for those who were using the *MyFeros* Portal.

The Portal also supports a wide range of technology-enhanced services and timely communication between staff, volunteers and consumers and used in combination with Google Assistant, it allows consumers to find information about upcoming appointments or carer visiting times, as well as information about their accounts and whether they have any messages, simply by saying '*Hey Google, ask Feros Care*'. Analysis of usage shows that the most common initial commands begin with requests for the day's weather and latest news, followed by queries about

[25] https://voicebot.ai/2019/05/23/alexa-skill-aimed-at-assisting-alzheimers-patients-launches-in-the-uk/

which Feros Care worker will be visiting that day, whether there are new messages and when the next service will be provided.

The partnership with Google enables Feros Care to leverage from their ongoing innovation and to access all new products. Feros Care intends to extend the program to become a standard offering for clients and to incorporate Artificial Intelligence and automation technology. For example, this could allow consumers to receive medication reminders, to initiate music therapy designed for those with dementia or to provide health monitoring information to Feros Care (e.g. measuring their blood pressure or weight with approved, but inexpensive devices).

At a cost of $40 per Google Assistant, this can deliver basic telecare without the expense associated with video technology, with the information provided able to be studied via data analytics, and in turn, supporting proactive care. Although it requires internet access, Google Assistant can operate over low bandwidth making it accessible in most parts of Australia.

How one visit changed Pamela's life

The empowering nature of this initiative is evident at the individual consumer level. Pilot participant Pamela Hanley, aged 73, returned home from a short hospital stay and relied on the technology to do so. Her MyFeros account was connected with Google Assistant via Google Home – a smart speaker that allows users to use voice commands to seek information and interact with services. Pamela can monitor and reschedule her upcoming services and carers, access her financial account and share messages with staff – all without picking up the phone.

Pamela commented -

"I couldn't get out of bed to use the computer but was able to ask Google Assistant what Feros Care services I had that day, which staff were coming to see me, and at what time. I've found it to be an excellent tool and I just hope people use it. They certainly shouldn't be daunted. I would be lost without MyFeros portal now."

Pamela Hanley and another Feros Care consumer who is living with multiple sclerosis discuss the positive impact on their lives made by this integration of voice-activated technology into their care at https://www.youtube.com/watch?v=9e84zw_q8TQ&t=30s

Feros Care has granted permission to the ACIITC to include this Case Study in this Literature Review

2.3 Technology-based Chronic Disease Management

The management of chronic health conditions is a critical issue for older people, health and aged care providers and the resourcing of the systems supporting them. Digital technology has an important role to play in this, but this is being pursued to a far greater extent by the health sector (*eHealth*) than by aged care providers, with significantly under-developed potential in the aged care sector.

2.3.1 The tele-technologies and their role in chronic disease management

The tele-technologies are a cluster of related services that provide remotely delivered care and support, and address access barriers, particularly distance. Definition of the different variants of services involved in this cluster are provided in the shaded boxes below.

TELEHEALTH

Telehealth involves the *"… use of telecommunications and virtual technology to deliver health care outside of traditional health-care facilities"* and as the *"… most basic element of 'eHealth' which uses a wider range of information and communication technologies (ICTs)"* (WHO 2010) https://www.who.int/sustainable-development/health-sector/strategies/telehealth/en/

Telehealth can involve a broader scope of remote healthcare services than telemedicine, such as provider training, administrative meetings, and in-service medical education, in addition to clinical services. It has been described as having the advantage of being able to diagnose faster, identify potential medication interactions, and update and secure health records in real-time (Tegart et al 2014: 8).

TELEMEDICINE

Telemedicine signifies the use of various types of ICT to a) provide clinical support b) overcome geographical barriers, connecting users who are not in the same physical location and c) with the goal of improving health outcomes. (WHO 2010) https://www.who.int/goe/publications/goe_telemedicine_2010.pdf

TELECARE

While *Telehealth* services are delivered at home via information and communication technologies (ICTs), *Telecare* involves the use of (usually, sensor-based) alarm systems and monitors installed in the home and capable of alerting significant others, health services and care providers when something occurs that is out of the ordinary, signalling a possible crisis. It has been defined as – *"… the continuous, automatic and remote monitoring of real-time emergencies and lifestyle changes over time in order to manage the risks associated with independent living."* (Telehealth and Telecare Aware) http://telecareaware.com/what-is-telecare/

MHEALTH

The proliferation of mobile devices (phones, personal digital assistants and other wireless devices represents a group of technologies that can contribute positively to health. These are known as *mHealth* which is a component of *eHealth* (WHO 2011). https://www.who.int/goe/publications/goe_mhealth_web.pdf

Telehealth, Telecare and other virtual models of care and support are increasing due to growth in both the use of internet-based technologies (e.g. Smartphones, tablets and computers) and the growing number of homes having access to wireless internet or NBN. This is creating increased opportunity for service providers to create new models of care and support where clients can connect more easily and more often connect to social programs, rehabilitation programs, education programs and to health professionals and case managers.

The tele-technologies are central to technology-enabled management of chronic illnesses and a significant portion of the research literature related to the care of older people with these conditions is focused on the use of *telemedicine*. Chronic conditions such as cardiovascular disease and diabetes can be monitored remotely, for example, by the measurement of vital signs (including temperature, blood pressure and respiration), measuring blood glucose levels and heart rates. Technologies being applied to transmit the resulting data to clinicians include remote monitoring equipment as well as computers, mobile phones and tablets. This is now a field of *rapid growth* in the research literature (Wootton 2012: 212).

EFFECTIVENESS OF TELEMEDICINE

Reviewing the literature as a whole, *telemedicine* emerges as very effective in managing chronic health conditions, improving functional status, general health and wellbeing. The systematic review by Khosravi and Ghapanchi (2016) concluded that of all the technologies studied for their effectiveness, *telemedicine* was the only one applied to assist older people living with a chronic health condition to show 'significant changes' that ranged from improvement in condition to reduced hospital readmission (Khosravi & Ghapanchi 2016: 23). Similarly, another systematic review of research based on 141 randomized controlled trials (RCTs) (representing a total of 37,695 patients) associated with telemedicine applications to common chronic diseases found that most reported favourable outcomes (Wootton 2012: 213).

Positive findings of the effectiveness and impact of ICTs on five major chronic diseases were identified in a scoping review undertaken by Wildevuur & Simonse (2015). This investigated the extent, range, and nature of ICT based interventions (primarily telemedicine) in the management of diabetes mellitus, cardiovascular disease, chronic respiratory disease, cancer, and stroke by analysing findings from 350 studies published between 1989 and 2013. The highest impacts were found to involve increased consumer empowerment (15.4% of studies), improved clinical outcomes (11.7% of studies), and decreased hospitalisation rates (12.3% of studies). Most of these findings were supported in another review that identified positive impacts on clinical processes and consumer health outcomes, as well as positive clinician and consumer satisfaction (Vedel et al 2013: 1111, 1115).

Another systematic literature review reviewed the effectiveness of ICT in-home care as a communication point between consumers, family members, and health care professionals. Most of the studies included had involved the care of people with chronic illness. There was a trend across these studies for different ICT applications in-home care to be received positively by people living with chronic illnesses and by health care professionals. Most studies showed that communication between health care professionals and patients living at home was improved by the use of ICTs, which were also regarded as useful in follow-up care of patients at home (Lindberg et al 2013: 6).

EFFECTIVENESS OF MHEALTH

A recent systematic review was undertaken to isolate the findings of randomized controlled trials (RCTs) regarding *mHealth* (Lee et al 2018). Of the 12 RCTs reviewed, 10 of the *mHealth* interventions demonstrated statistically significant improvement in some health outcomes. The most common features of *mHealth* systems used in the reviewed RCTs were real-time or regular basis symptom assessments, pre-programmed reminders, and feedback relating to the data provided by participants via *mHealth* devices. Most studies had developed their own *mHealth* systems including mobile Apps. The *mHealth* interventions reviewed had been developed specifically as disease-specific interventions, and the authors note that these are likely to be different from commercial mobile health Apps available to the public.

Among the *mHealth* approaches found to enhance self-management of chronic health conditions were a) automated text reminders, b) frequent and accurate symptom monitoring (often in real-time), and c) improved communication between patients and healthcare providers. However, gaps in the evidence base were also found, including:

- the need for longitudinal assessment of impacts on individuals and their caregivers
- identification of the optimum length of time and frequency of *mHealth* interventions
- improved understanding of the relationship between user engagement with *mHealth* tools and outcome improvement and
- development of 'rigorously tested' *mHealth* Apps based on research evidence, making these available to the general population (Lee et al 2018).

TECHNOLOGY SUPPORTING SELF-MANAGEMENT OF HEALTH

These technologies also support *self-management* of health, which research has found to be effective in addressing chronic health conditions because the consumer is more actively engaged in the process and therefore more likely to take ownership of their health (Pellegrini et al 2014; Morrison et al 2012). Their use can improve health status, increase symptom control and thereby reduce the use of general practitioners and admissions to a hospital (Tegart et al 2014). Such outcomes also bring benefits in the form of cost savings and efficiencies to health systems, and to individuals in the form of improved health and greater control over the management of their condition. Evidence is growing about their effectiveness. In Australia, the CSIRO Home Monitoring project highlights what is possible – see Case Study 2, Section 2.3.2 below.

Please refer to Destination 2: Technology-enhanced Care and Support for Older People of the *Technology Roadmap for Aged Care* for a discussion of the importance of monitoring technologies in improving health and care outcomes.

Australian research by the CSIRO (2016) –see Case Study 2 below - has identified significant changes in health outcomes for participants in its *Telehealth* project, and for the health system, including:

- a 36 per cent decrease in hospital admission and a 42 per cent reduction in length of stay if admitted to hospital during the 12-month trial; and
- a reduced mortality rate of more than 40 per cent among participants.

2.3.2 Case Study 2: CSIRO Home Monitoring of Chronic Disease for Aged Care

CSIRO HOME MONITORING OF CHRONIC DISEASE FOR AGED CARE TELEHEALTH PROJECT

This two-year project (2013-2014), Australia's first multi-state and multi-site randomised controlled trial of *Telehealth,* sought to develop advanced modelling and data analytics while supporting chronically ill people through home-based Telehealth services.

Six fibre and fixed-wireless NBN-connected sites around Australia provided the location for the project and involved a diverse range of care models. Each site involved both participants in the home monitoring services and control patients who received usual care services. A total of **287** patients participated in the trial and were supported with Telehealth devices that included participant/clinician video conferencing capabilities, messaging features and the delivery of clinical and study-specific questionnaires, as well as vital signs devices to monitor their heart rate (electrocardiogram), blood pressure, oxygen saturation (spirometer), body weight and body temperature, with provision of a glucometer an optional add-on for people with diabetes. Important outcomes from this project were identified for **both** participants and the health system:

- ✓ the significant change in the way participants understood their health condition and adapted their behaviours accordingly – highlighting the important role of *health literacy* and *self-management* of health and the role of technology in enabling this outcome;
- ✓ reported improvements in anxiety, depression and quality of life;
- ✓ savings to the healthcare system through reduced falls, reduced number and cost of GP visits, specialist visits and procedures;
- ✓ a 36 per cent decrease in hospital admission and a 42 per cent reduction in length of stay if admitted to hospital during the 12-month trial.
- ✓ a reduced mortality rate of more than 40 per cent among participants.

The project was funded a total of $5.47 million by the Australian Government Telehealth Pilots Programme, CSIRO and project partners. This funding proved to be a good investment, yielding a return on investment in the order of 5:1 due to reduced use of hospital inpatient and outpatient services, GP visits, community nurses visits and overall reduced demand on increasingly scarce clinical resources.

CSIRO (2016) http://www.csiro.au/en/Research/BF/Areas/Digital-health/Improving-access/Home-monitoring

2.3.3 The monitoring technologies and their role in chronic disease management

The various monitoring technologies enable care providers to determine health-related status virtually, and outside of clinical settings – in people's homes or whatever location they happen to be visiting. Not only does this create greater flexibility of care but it also enables data to be captured in 'real-time'. Sensor technologies (including Wearable sensors) play a prominent role in remote monitoring and remote delivery of health consultations. Next-generation monitoring technologies apply machine learning technology that enables them to learn behaviours designed to support prevention and early detection of health issues (such as infection, reduction in mobility or increase in dementia-related behaviours).

Typically, these technologies involve installing alarm systems and monitors that are capable of alerting service providers, carers or other supporters when something occurs that is out of the ordinary. Sensors are usually non-intrusive and rely on infrared or movement sensors that are embedded in the environment. Sensors are now significantly more-portable because they are designed to be *wearable*, and because of advances in nanotechnology, can take the form of *implantable* or injectable sensors that support personalised treatment (but will be available for care providers further into the future).

While the use of monitoring technologies is driven largely by the health sector, these could also be used by the aged care sector (in both residential and community services), ideally based on partnerships between both sectors and with key technology providers. Monitoring technology holds significant potential for supporting older people but, as with the broader literature, there is a need for well-designed studies involving larger sample sizes, over longer periods of time, in order to evaluate cost-effectiveness and capacity to prolong independent living (Peetoom et al 2014: 291).

2.4 Technology-based Monitoring and Surveillance

A range of monitoring and surveillance technologies exist that can enable older people to continue living in their own homes, noting that this will involve a trade-off for them between privacy and independence (and between the older person's desire for this and the peace of mind of their supporters). There is a tension between these trade-offs which is particularly evident in relation to the more intrusive monitoring technologies.

It is important to recognise that a *continuum* of monitoring technologies exists, ranging from least to most intrusive as well as from least to most effective in enabling quality of care and promoting safety. Sensors sit at the least intrusive end of this continuum while video surveillance is far more intrusive and, therefore, the least likely to be regarded as acceptable by older people (often in contrast to family carers' wishes for their safety) (Hawley-Hague et al 2014). This range is illustrated in the Fall Detectors – discussed in greater detail in Section 3.2, together with the role of sensor technology.

2.4.1 Fall Detectors: Illustrating the Range of Monitoring Technologies

At present, the aged care sector has been made highly aware of video surveillance through a series of incidents in residential aged care facilities that documented the abuse of older people, but there is a need to acknowledge that this is but one in a range of monitoring technologies, and to discuss the place of all of these in the care system. The need for a more *nuanced* approach is illustrated in relation to fall detectors. These can be broadly categorised into three groups, each of increasing technological sophistication and reflecting a shift from "Consumer-Push" to "Data Pull" initiation:

1. *First-generation* systems involve alarms relying on the user to detect the fall. Typically worn as a pendant around the neck, the user must push a button to contact a call centre or emergency services. These can be stigmatising and rely on the older person to be wearing them at the time of a fall.

2. *Second-generation* systems augment first-generation systems with an embedded level of intelligence. These comprise fall detection devices worn by the person that can trigger a call for assistance automatically without having to press a button.

3. *Third-generation* systems use data, often via ambient monitoring systems, to detect changes (e.g. in activity levels) that may denote an increased risk of falling and support a preventive rather than reactive approach. Examples include the development of 'smart shoe insoles' that can send data regarding the wearer's gait to a central database, detecting changes in gait to prevent a fall; incorporating a fall detector into a walking stick able to measure abnormalities in gait which could predict increased fall risk; and embedding fall detectors into a 'smart floor' to detect whether the carpet is being walked on, or whether someone is lying prone on the floor (Ward et al 2012; Maki et al 2011). Recent technologies that facilitate correction of imbalance are an emerging fall prevention technology, as seen for example, in the *B-Shoe*.[26]

ETHICAL IMPLICATIONS OF MONITORING AND SURVEILLANCE TECHNOLOGIES

Awareness of video surveillance technology has increased significantly in recent years as a growing number of homeowners use it to protect their properties, More broadly, this reflects the need to continue sector-wide conversation about all forms of surveillance and their appropriate role in care provision (initiated by ACSA and the Older People's Advocacy Network (OPAN), both of whom have developed Draft Position Statements on this issue).

2.4.2 Addressing older people's attitudes to falls management technology

Regardless of how effective the technology, it must be acceptable to the older people for whom it is intended. A systematic review provides useful information about older adults' attitudes to technologies aimed at falls prevention, detection or monitoring (Hawley-Hague et al 2014) with much of the information being applicable to the adoption of other technologies able to assist in independent living at home. Across 21 studies reviewed the following key insights emerged:

- **Control** over the technology and how it is used is very important to older people, particularly with regard to the protection of privacy. For this reason, video imagery depicting them after falling is seen as highly intrusive while alarms that cannot be turned off (e.g. when falsely activated) are unlikely to be used, mainly because of not wanting to 'bother' significant others and care workers, but also because of the nuisance caused to the person.
- Linked to control over technology was **choice** of technology, with preference for user-friendly technology that older people are able to manage, thereby enhancing choice and control. The importance of tailoring assistive technologies to individual need and preference is reinforced by this finding. Attitudes to both choice and control reflect the importance of technology in supporting or enabling **independence.**
- Perceived **relevance** to individual need also emerges as affecting uptake, particularly for older men.

[26] https://b-shoe.com/

- Technology is also more likely to be used if it is perceived to improve personal **safety**, particularly in relation to real-time monitoring and connection to response systems.
- **Usability, reliability** and how well the technology **integrates into the home** also affect adoption and long-term use of technology. Large buttons and easy to read screens and signs are part of this, as are design aesthetics – older people do not want technology that identifies them as 'fallers' or that makes their home look like a hospital or other institutional environment (Hawley-Hague et al 2014: 422-424).

2.5 Technologies that support enhanced social, emotional and psychological wellbeing

Based on systematic reviews of the research evidence, there has been growth in technology-based interventions designed to address isolation and enhance social connection, in the process of improving emotional and social wellbeing. However, addressing psychological wellbeing with technology appears to be a less developed field (in terms of reliable studies) with a relatively small number exploring the role of technology in reducing depression.

2.5.1 Technologies designed to reduce isolation and enhance social connection

Social isolation and loneliness have a negative effect on the health and wellbeing of older people. Various technology-based interventions exist to reduce social isolation but research demonstrating their effectiveness among older people is limited. A shared conclusion across all studies reviewed is that there is a need for further research on the role technology can play in reducing isolation and increasing social connectedness (Baker et al 2018; Khosravi, Rezvani & Wiewiora 2016).

Technological interventions to reduce social isolation and loneliness were grouped into eight main categories by a recent systematic review: general ICTs, video games, robotics, Personal Reminder Information and Social Management system (PRISMS), asynchronous peer support chat rooms, social network sites (SNSs), Telecare, and 3D virtual environments (Khosravi, Rezvani & Wiewiora 2016). Most of the studies (with 15 publications in the final set) evaluated the impact of general ICTs on social isolation and loneliness. On the whole, findings were mixed. Inconclusive results were found for social network sites, and promising results for PRISMS and video games, with more research needed to be able to generalise the positive findings of a few well designed and conducted studies. The most positive findings were associated with *Telecare,* followed by general ICTs and then by robotics. Seven studies found general ICTs, strategic use of the Internet and social media, computer training and usage, mobile remote presence robotic systems and pet-type robots to be effective in reducing isolation, increasing social connection and quality of life as well as producing other benefits.

Other systematic reviews focused on social support interventions found that statistically significant improvements occurred most consistently when applying smart technology (usually an interactive, online program incorporating health information, chat rooms, discussion boards or support groups) over periods of less than one year. Three out of five studies identified enhanced empowerment for participants in these programs.

One review of technologies designed to reduce social isolation found that information and communication technologies (ICTs) can improve social wellbeing more than non-ICT technologies. However, to be effective they require a degree of technology literacy which cannot be guaranteed for all older people or their carers (Pinto-Bruno et al 2016).

Alcove is a virtual reality platform designed to remove social isolation barriers and to connect family members across generations by enabling them to share immersive experiences, deepen bonds and create new memories as a family. Developed by *AARP Innovation Labs* (https://aarpinnovationlabs.org/our-products/) in partnership with *Rendever* — a start-up focused on virtual reality technology.

Alcove seeks to bridge the physical distance between family members and enables participants to experience new places and things that they would not otherwise be able to do due to cost, time or mobility constraints. Users enter and navigate on their own or in multiplayer mode with their family and friends. See more at https://alcovevr.com/

Mixed results have been found for technologies' impact on loneliness (Chen & Schultz 2016; Morris et al 2014) but of course, this is a much more complex issue to address than isolation. Another systematic review of e-interventions for loneliness in older people living in the community or in residential care concluded that while studies showed a lack of rigour, there is inconsistent and weak evidence supporting the use of e-interventions to address loneliness in older people (Chipps et al 2017).

2.5.2 Technologies designed to reduce depression and enhance psychological wellbeing

A recent systematic review explored the effectiveness of technology-based interventions in promoting the mental health and wellbeing of people aged 65 and over. It found a paucity of methodologically sound studies resulting in an inconsistent evidence base of what was deemed to be only moderate in strength and quality (Forsman et al 2018).

However, three of the six studies reviewed rated as having high or moderate quality of method (all of which focused on training in computing and Internet use) and reported statistically significant positive effects on psychosocial outcomes, including a) increased life satisfaction b) improved social support c) reduced depression levels d) reduced loneliness e) increased life satisfaction and f) enhanced quality of life (Forsman et al 2018: 1051).

SMARTPHONE APPS FOR TREATING DEPRESSION SYMPTOMS: ENCOURAGING POTENTIAL

The first meta-analysis of Smartphone Apps for the treatment of depression symptoms (Firth et al 2017) identified 18 randomized controlled trials of 22 Smartphone Apps, with outcome data from 3,414 participants. Findings were encouraging with depressive symptoms reduced significantly more from Smartphone Apps than Control conditions ($p<.001$). However, this applied to those with self-reported mild to moderate depression, and particularly when Cognitive Based Therapy (CBT) interventions were involved. There was no significant effect identified for major depressive, bipolar or anxiety disorders.

The authors noted that this field can be expected to grow, with 14 of the 18 eligible studies published in the preceding two years. They concluded that Smartphone Apps offer a promising self-management tool for depression (Firth et al 2017: 287).

2.5.3 A role for robotics

DEFINITIONS OF DIFFERENT TYPES OF ROBOTS

Socially Assistive Robots are designed to assist people with a range of daily tasks and to assist with social interaction by engaging users in lifelike social behaviour (Moyle et al 2017: 4). Within this category, a further four types of robots have been identified:

- *Healthcare robots* - promote or monitor health in order to prevent further health decline.
- *Rehabilitative robots*- perform physical tasks or make tasks easier for people with physical or functional limitations.
- *Social robots* – sometimes called *Emotional robots* designed to provide emotional support including companionship (without also assisting with tasks).
- *Service robots* - provide assistance with mobility, household tasks and health monitoring (but are not designed to provide companionship or emotional support).
- *Telepresence robots* - provide both companionship and assistance with the addition of videoconferencing technology (Moyle, Arnautovska et al 2017: 3-5, citing Robinson et al 2014).

There are a number of ways robot technologies can assist older people to live independent lives, with two types featuring in the literature – pet or companion type robots, and lower limb ATs that assist with mobility (most of these being exoskeletons that are fitted to the outside of the limbs). The majority of studies focused on the latter group of technologies have been limited to controlled laboratory settings or a laboratory situated within a clinical environment. Social robots designed to communicate and interact with people offer the potential to contribute to improved social and emotional health outcomes. However, evidence from randomized controlled trials (RCTs) on health and well-being outcomes requires further development (Morris et al 2014).

Nevertheless, our understanding of the potential roles this technology can play are clearer. One recent review of the use of Socially Assistive Robot technology identified five roles in its application in the care of older people: affective therapy, cognitive training, social facilitation, companionship and physiological therapy (Abdi et al 2017). Another major study concluded that Social Assistive Robot technology has the potential to enhance the wellbeing of older people and to decrease the workload of caregivers (Kachouie et al 2017).

An Australian review of 1,035 studies focused on the use of *Telepresence robots* to improve social connectedness in people with dementia and identified only four eligible peer-reviewed publications (Moyle, Arnautovska et al 2017). These studies reported positive outcomes associated with using *Telepresence robots* to connect people with dementia to others, as well as barriers that included technological issues and lack of experience in using a robot. The authors concluded that despite being limited, the existing research evidence base "… *suggests that telepresence robots have potential utility for improving social connectedness of people with dementia and their carers.*" However, more systematic feasibility studies are needed to be followed by clinical trials (Moyle, Arnautovska et al 2017: 22).

Social robots appear to have positive impacts on agitation, anxiety, and quality of life for older adults, but no statistical significance was found in a meta-analysis of nine studies. It was concluded that social robots 'appear to have' potential to improve older people's wellbeing, but the lack of research-based on reliable methodology (only 11 Randomized Controlled Trials were identified from 2,204 publications) made it impossible to draw firm conclusions about their effectiveness (Moyle et al 2017).

PET ROBOTS

Pet-type robots have been found to be effective in reducing depression and stress levels, improving mood, and reducing social isolation (Khosravi & Ghapanchi 2016). However, the research evidence base is still growing.

A recent systematic review of the efficacy of Pet Robot intervention for people with dementia (Minmin et al 2019) identified only six randomized controlled trials from 980 publications focusing on this intervention. The results of this meta-analysis showed a statistically significant decrease in behavioural and psychological symptoms of dementia (BPSD), especially agitation and depression, in people with dementia who were treated with Pet Robot interventions, but no significant improvements in cognitive function or quality of life. The authors concluded that Pet Robot interventions could be a suitable treatment for BPSD in people with dementia and a useful tool for clinical practice (Minmin et al 2019: 523).

A cluster-randomized controlled trial conducted in 28 residential aged care facilities in south-east Queensland tested the effects of PARO (Version 9) on the emotional and behavioural symptoms of 415 people living with dementia in those facilities (Moyle, Jones et al 2017). The PARO, which resembles a baby harp seal and is designed to mimic animal behaviours, was compared with a look-alike plush toy and usual care. This study was described by its authors as the largest and most rigorous of the PARO studies conducted at that time and provided important additional information because of its methodology. This left participants to decide how they would interact with and use PARO, whereas all previous studies had used a human to facilitate engagement, making it difficult to separate effects of the PARO itself from the human facilitation. Unlike a few previous studies, this study also compared PARO with a similar soft toy and usual care control.

PARO was found to be more effective than usual care in improving mood states and agitation, but only more effective than a plush toy in one outcome area, namely, encouraging engagement (Moyle, Jones et al 2017: 772). The authors concluded that while these findings partly supported the efficacy of PARO, they also indicated that aged care providers with limited resources could use a soft toy animal effectively with someone living with dementia, and that PARO should not be used as a replacement for care workers but rather to compensate for staff being busy with other tasks or as a comforting mechanism (Moyle, Jones et al 2017: 772).

Analysis from a recent systematic review of evidence from randomized controlled trials on the effects on health and wellbeing of psychosocial interventions by social robots identified 27 trials from 408 publications, of which 12 involved older adults. Most of the research examined the effectiveness of social robots (frequently involving the PARO seal) in improving cognitive and/or psychological functioning or neural integrity, and one focused on self-management of chronic obstructive pulmonary disease (COPD). Eight trials involved older people living in residential care (Robinson et al 2019).

This review concluded that the evidence for health, wellbeing, and psychosocial interventions delivered by social robots remains at an early stage, with promising findings on a number of dimensions based on a small number of trials. The table below summarises those findings from the 12 trials involving older people, by the number of trials identifying each type of impact.

TABLE 1: IMPACT OF SOCIAL ROBOTS ON WELLBEING AND PSYCHOSOCIAL HEALTH

Findings regarding Social Robot impact on older adults' social & emotional wellbeing and psychological health	No of trials (out of 12)
Positive impact on emotions including expressions of happiness	3
Reduced agitation	3
Decreased scores on loneliness	2
Decreased depressive symptoms	2
Improvement on quality of life measures	2
Improvement on quality of life measures only for severe dementia	2*
Source: Robinson et al 2019: Table 3 pp 10-14	

* 2 different trials

However, some trials found variation in impact based on individual differences, such as, in existing levels of agitation at baseline, and negative impact in some areas, for example, levels of irritability (one trial). One trial identified inconsistent emotional impact (Robinson et al 2019: 14).

Please refer to Destination 2: Technology-enhanced care and support for older people of the *Technology Roadmap for Aged Care* for a discussion of the issues associated with supporting independent living and wellbeing, and the actions needed to implement this Destination in Australia.

2.6 TECHNOLOGIES DESIGNED TO SUPPORT FAMILY CAREGIVERS

As Australian aged care shifts increasingly to community-based care, the role of family caregivers will become even more important because they are often the linchpin in this model. ABS surveys of carers repeatedly show that the key motivator for them is a wish to provide the best possible care and to fulfil family obligations. Those drivers can be addressed by many of the technologies discussed so far (and some of those in Section 3 – such as, medication management and falls devices) without necessarily having been designed with the needs of family carers in mind. For example, monitoring technologies can allow older people to live independently while providing their supporters with peace of mind regarding their safety. Being able to communicate virtually can reduce carers' anxiety about not being able to be physically present. Much of the technology associated with Smart Homes benefits carers indirectly while being of direct benefit to older people living in these environments.

There is a limited but growing amount of reliable research in the current literature on the impact of technology on informal carers, although that which exists has a strong emphasis on carers of people living with dementia. Systematic reviews identify that technologies contribute to carers' wellbeing by reducing the amount of time, assistance and energy required to provide support and care, and by lessening anxiety and fear, task difficulty, safety risk (particularly for activities requiring physical assistance) while increasing the independence of the person in their care (Marasinghe 2016: 357, based on a systematic review of 10 studies).

There are a number of telemedicine technologies designed to provide information, education and support to family carers. A review of telehealth interventions designed to support family caregivers identified an increasing use of videoconferencing / videophone (particularly for providing education to caregivers, conducting telehealth consultations for both care recipient and caregiver, providing social support) and remote monitoring of the person receiving care to reduce caregiver workload (Chi & Demiris 2015: 38-41). Telemedicine and monitoring technologies have been found to be effective in reducing carer stress and sense of 'burden'.

However, caregivers' relationship with technology is complex as the workload related to caregiving can itself be a barrier to adopting, experimenting and using technology, while reducing that workload can be an enabler to technology usage (Marasinghe 2016 citing Boger et al 2014;[27] Bowman et al 2013[28]). Obviously, individual carer situations will be affected by a range of variables including the severity and type of need of the person in their care, the dynamics of the caregiving relationship and other family relationships, individual resilience and readiness or capacity to engage with technology. Adding to the complexity is that some care recipients express concern that the additional communication with family members enabled through monitoring and video communication technology will intensify caregiver workload (Marasinghe 2016: 358).

A recent systematic review of 16 studies focused on the experiences with assistive technologies (ATs) of carers of people with dementia living at home and the impact of those ATs on their health and wellbeing. This found that the most commonly used technologies were those addressing safety and security, including tracking and home safety devices which were perceived as extremely beneficial for both carers and the person with dementia. These

[27] Boger J, Quraishi M, Turcotte N et al (2014) The identification of assistive technologies being used to support the daily occupations of community dwelling older adults with dementia: a cross-sectional pilot study, *Disab Rehab Assistive Technology*, 9: 17-30

[28] Bowman S, Hooker K, Steggell C et al (2013) Perceptions of communication and monitoring technologies among older rural women: problem or panacea? *Jl Housing Elderly*, 27: 48-60

were followed by devices used for supporting memory and orientation for the person living with dementia, and by those for social interaction and leisure activities (Siriam et al 2019: 13).

There were no significant changes in carer reported wellbeing or 'burden' but the additional personal time gained was highly valued. In part, this could have been due to technologies addressing only a few of the issues that create the greatest stress for carers of people with dementia, including repetitive questions, apathy, getting lost, aggression and incontinence. The technologies involved in this review were not designed to address these behavioural challenges, with the exception of exception of safety and tracking devices (Siriam et al 2019: 18). This review also identified strategies for enhancing the use of technologies, in particular:

- Providing information about potentially useful technologies early in the process of diagnosis.
- Ensuring that this information led them to user-friendly and practical AT solutions. Most carers were unaware of new and available technology supports (Siriam et al 2019: 20).

An earlier systematic review of research studying the effectiveness of Internet-based, caregiver-directed interventions (Hu et al 2014) identified mostly positive findings from randomised controlled trials (RCTs). These found a significant reduction in caregiver 'burden', depression, pain and stress among carers of people with dementia and significantly improved mental health status, self-efficacy, and social support (Marziali & Garcia 2011; Lorig et al 2012). Interventions were diverse and included Internet-based chat support groups, an Internet-based skills enhancement workshop, an interactive learning centre, bulletin boards, individualised problem behaviour diaries and exercise logs, and ongoing communication.

A more recent systematic review and meta-analysis examining the impact of Internet-based interventions on the mental health outcomes of carers of adults with chronic conditions living in the community identified 'small to moderate beneficial effects' of these interventions on carers' mental health. These included a reduction in symptoms of depression, stress, distress, and anxiety. The types of Internet-based interventions producing these outcomes included information or education only (decreasing depression, stress or distress, and anxiety) and information or education plus professional psychosocial support (reducing depression and anxiety). However, the authors also identified the need for more large scale, methodologically sound research on this relationship (Sherifali et al 2018).

3 TECHNOLOGIES THAT SUPPORT AND ENHANCE THE CARE OF OLDER PEOPLE

3.1 ASSESSMENT OF NEED

Assessment is one of the most critical components of the aged care system with a dual function – acting as a gatekeeper to the system's resources and shaping the individualised plan of care designed to respond to the needs identified. As technology evolves, its contribution to the tailored supports designed for aged care consumers is significant, but this is not reflected in the aged care system's requirements for assessors (neither for entry to residential nor to community care). Whether or not new technologies that can transform the capacity for independent living will or do form part of the service response is a matter of chance, rather than design, and will depend on individual assessors' familiarity with these potential solutions (ACIITC 2017: 22-24).

One systematic review identified 474 studies involving 166 different functional assessment tools and found that over time (from the 1960s onwards) these tools had gradually evolved from assessing individual ability to perform the most basic everyday tasks, to assessing a wider range of aspects of a person's life including cognitive, emotional and social abilities (Lowe et al 2013: 621). Tellingly, the ongoing evolution had occurred in parallel to technological change but had *failed to integrate* those advances.

> ***Despite the availability of technology that supports assessment of function and need these technologies are not an embedded feature of assessment processes. These technologies have the capacity to save resources in the resource-demanding aged care sector, increase time savings, improve the capacity to track and maintain client records, facilitate more effective assessment and monitor changes in capacity. Some technologies, for example, sensors, can yield information which a single or even repeated assessments may miss (ACIITC 2017: 24).***

In part, this reflects an absence of supporting systems for technology-enabled assessment (Lowe et al 2013) but it may also be that while those performing assessment roles have the clinical knowledge required, they do not have the training, skills and knowledge of technologies to enable efficient and effective uptake.

At present reviews by aged care service providers are undertaken (in most instances) by administering assessment instruments manually, at isolated intervals and without the benefit of 'real-time' data collection. There is scope for greater use of technology-enabled assessment, allowing for more frequent assessment in 'real-time' as well as for self-administration by consumers - empowering them to play a more purposeful role in monitoring their status over time. Smartphones also offer significant promise because of their ability to capture a range of data, including sensor-based information, making assessment a portable activity whose data can be analysed anywhere at any time. Their increasing ownership by older Australians, with agreed and appropriate Apps installed, makes them a potentially vital part of assessment infrastructure.

Reviewing the available research, there are two trends evident. The first involves the application of technologies, particularly sensors, to accurately measure functional capacity in 'real-time', to send that data to service providers, and to automate assessment. The second is associated with the evolution of Smartphones whose inbuilt sensors can be utilised in assessment, involving consumers in the assessment process, and capturing real-time data rather than episodic data (as occurs through appointed assessment sessions).

The commonly used assessment tool *TUG (Timed Up and Go)* assesses the risk of falling and related functional decline. One systematic review of research reviewed studies that had applied new technologies (video-based, wearable, smartphone-based and ambient) to its administration (Sprint et al 2015). *Ambient sensors* able to capture such variables as temperature, light and motion, and able to be embedded in a range of household objects, were used in another study to estimate speed of walking while a sensor-enabled chair was designed to automate TUG assessment *(aTUG).* This avoided the need for wearable sensors, offered scope for older people living at home to self-administer the TUG, and the potential to be further developed into a 'smart chair' capable of also collecting various biometric information (Sprint et al 2015: 12 citing Frenken et al 2011).

In one study, a self-administered, Smartphone[29] application that completely automates the TUG *(the sTUG)* was trialled (Milosevic et al 2013). The application provides instantaneous feedback to the user and allows for automatic uploads of the results into their medical record. Following tests on a group of healthy volunteers and people living with Parkinson's Disease, the sTUG was found to be affordable and offering immediate quantification of TUG results (Milosevic et al 2013: 6).

Another study analysed the suitability of a range of ambient technologies for home-based assessment of the functional status of older people. These involved a portable force platform, the aTUG system, a hand-grip dynamometer, a stadiometer, a bio-impedance measuring device, and a light barrier measuring system. In addition, participants wore a sensor belt by *Humotion* [30] to determine whether this would yield equivalent or improved information than traditionally measured geriatric assessment. The researchers concluded that these technologies were a) able to support and enhance clinical assessment of functional status, b) were acceptable to users and c) were suitable for ambient home assessments (Helmers et al 2017: 14).

Automated assessment is likely to be a further feature of technology-driven assessment reform, assuming it can achieve a high utility to cost ratio and support scalable health and aged care (Sprint 2015: 13). Automated assessment of rehabilitation exercises, therapy programs, and clinical measures are a large part of the future of healthcare (Sprint et al 2015: 13).

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[29] sTUG is developed for Android operating systems and requires a smartphone with the accelerometer and gyroscope sensors running Android 2.3 or above (Milosevic et al 2013).

[30] A diagnostic tool used with athletes that integrates lightweight sensor electronics into a textile belt in order to assess performance. The belt includes four sensor types -a triaxial accelerometer, gyroscope, magnetometer and barometer. - https://humotion.net/en/products/smartracks/diagnostics/

Please refer to Destination 4: Technology-enabled assessment of eligibility and changing need of the *Technology Roadmap for Aged Care* for a discussion of the issues associated with technology-enabled assessment, and the actions needed to implement this Destination in Australia.

3.2 Falls prevention, detection and management

Technology-based interventions are playing a growing role in falls prevention, through diagnosing fall risks, detecting falls and alerting clinicians in case of falls, managing medications, and increasing sustained engagement by older people in falls prevention interventions. Technology is also seen as having the potential to play a key role in enabling older adults to self-assess (Hamm et al 2016 citing multiple studies).

In relation to falls, assistive technologies can be divided into (1) those designed to *prevent* a fall from occurring; and (2) those which aim to *manage* the outcome of a fall after it has occurred. There is emerging evidence that falls could be prevented with appropriately designed intervention programs, although it is important to acknowledge that technology is a critical (but not stand-alone) component of overall falls prevention strategies.

The role of sensors

Sensor technologies have a key role to play in falls prevention and detection. Typically, these technologies involve installing alarm systems and monitors that are capable of alerting service providers, carers or other supporters when something occurs that is out of the ordinary. Sensors are usually non-intrusive and rely on infrared or movement sensors that are embedded in the environment.

Sensors are now significantly more-portable because they can be designed to be *wearable*, and because of advances in nanotechnology, will be able to take the form of *implantable* or injectable sensors that support personalised treatment (but will be available for care providers further into the future). *Wearable* technology has advanced significantly since the era of large and stigmatising alert buttons worn around the neck. This is due in large part to the recent popularity of lifestyle wearables like *Apple Watch* and *Fitbit,* which are being used widely by the general population for health promotion and are increasingly accessible and affordable.

Wearable sensors can measure users' manner of walking as a key indicator for predicting falls. When the device detects a change in gait, it alerts the users that they may be headed for a fall. Data collection using wearables in the daily living environment offers a unique insight into how different activities are performed and how these activities relate to fall risk. However, the number of studies investigating this approach is very limited at this stage (Hamm et al 2016; Danielsen et al 2016).

Inertial sensors can collect relevant data associated with gait characteristics. Accelerometers and gyroscopes have been used in this context in a number of studies. Combining *ambient* sensor data with sensor data from *wearables* is important to be able to recognise context and activity for falls prevention interventions (Danielsen et al 2016: 187-189).

THE INCREASING ROLE OF ARTIFICIAL INTELLIGENCE (AI)

Earlier technology-enabled falls prevention was based on the use of sensors but more recently, the addition of Artificial Intelligence (AI) enables an individualised record of normal and abnormal movement, analysis of which can generate *predictive* information. Prior to these developments in falls prevention, technology was focused on devices (mainly wearables) that provide an immediate alert that someone had fallen, triggering a response from a nominated responder.

This is part of a wider and growing trend to incorporate Artificial Intelligence with accompanying data analytics into health care programs. Next-generation monitoring technologies apply machine learning technology (Artificial Intelligence) that enable them to learn and analyse behaviours in 'real-time', supporting prevention and early detection of fall risk.

3.2.1 Falls detection technology

Apart from being important in alerting services and supporters to a fall event, if their detection is timely, fall detectors may reduce hospitalisation or shorten hospital stay (Steventon et al 2013: 502). Fall detectors exemplify the growing sophistication of technologies as they move from simple detection to fall prevention (as discussed in Section 2.4.1). Examples include:

- the development of 'smart shoe insoles' that can send data regarding the wearer's gait to a central database, detecting changes in gait to prevent a fall;[31]
- a fall detector incorporated into a walking stick that is able to measure abnormalities in gait which could predict increased fall risk;[32] and
- embedding fall detectors into a 'smart floor' to detect whether the carpet is being walked on, or whether someone is lying prone on the floor.[33] The 'smart carpet' also has the benefit that it does not require the user to remember to maintain batteries. It does this by using "energy scavenging sensors" that can harvest energy (such as light, thermoelectric and vibrational energy) from the surrounding environment (Ward et al 2012: 206-207: Maki et al 2011: 474).

Remote health monitoring and sensor technologies have been found to improve older people's safety and reduce their risk of falls (Khosravi P & Ghapanchi 2016: 18 citing Lancioni et al 2013; Cowan et al 2012). Fall risk assessment sensors and wireless bed sensors have been found to be effective technologies in reducing falls – each achieving an 18 per cent reduction in fall rates (Khosravi & Ghapanchi 2016 citing Lancioni et al 2013 and Cowan et al 2012).

[31] eg http://newamericamedia.org/2017/02/smart-soles-and-other-high-tech-ways-to-stop-falls.php
[32] eg https://pdfs.semanticscholar.org/abae/d0232d4f43b39d0a9cfda9838dad91f1bce1.pdf
[33] eg http://www.silvereco.org/en/sensfloor-a-smart-floor-to-detect-falls/

The *iStoppFalls* (Information and communications technology-based System to Predict & Prevent Falls) assessment system, is a Kinect (motion-sensing input device) and inertial sensor-based test that supports older people to undertake regular and *unsupervised* fall risk assessments at home. The *iStoppFalls* system was installed into the homes of 62 community-living older people in Australia, Germany, and Spain for the duration of four months. Participants were asked to perform at least 1 assessment each month. In total, 241 assessments were independently performed by the participants.

Most participants felt positive about their experience and could see themselves continuing with the assessment on a regular basis. The evaluation found that key success factors for using *iStoppFalls* were user motivation, the design and selection of appropriate tests, the reliability and usability of the applied technology, the frequency and duration of the assessment, and its safety and support features. The evaluation concluded that a sensor-based self-assessment for fall risk was feasible, but that further research is needed, with particular attention being paid to design requirements (Ejupi et al 2016).

3.2.2 Falls prevention technology

A recent systematic review by Sun and Sosnoff (2018) examined research evidence drawn from the period 2011 to 2017 regarding sensor technology used to assess fall risk in older people. Twenty-two studies were systematically identified and selected for review from 855 articles, based on rigorous inclusion criteria. This review filled a gap in the evidence base by synthesising findings of studies focused on specific types of sensors and identifying the range of sensors that can contribute to accurate prediction of falls. Steady state walking, static/dynamic balance, and functional mobility were the focus of assessment

- Four major sensing technologies (inertial sensors, video/depth camera, pressure sensing platform and laser sensing) were reported to provide accurate fall risk diagnostics, with sensing technology being found to constitute a viable assessment tool for fall risk assessment.
- Wireless pressure insole devices were found to have a role in fall prevention by continuously monitoring daily living activity and by deriving gait parameters for diagnostic purposes (Sun & Sosnoff 2018: 8 citing Di Rosa et al 2017 and van Schooten et al 2015).[34]

Overall, these sensor-based technologies were found to provide "... *accurate, inexpensive, and easy-to-administer objective fall risk assessment.*" However, the variation in measured parameters, assessment tools, sensor sites, movement tasks, and modelling techniques led

[34] Di Rosa M, Hausdorff J, Stara V et al (2017) Concurrent validation of an index to estimate fall risk in community dwelling seniors through a wireless sensor insole system: a pilot study, *Gait Posture,* 55: 6–11.

van Schooten K, Pijnappels M, Rispens S et al. (2015) Ambulatory fall-risk assessment: amount and quality of daily-life gait predict falls in older adults, *Journals of Gerontology Series A: Biomedical Sciences and Medical Sciences*, 70(5): 608–15.

the authors to conclude that further research was needed to accurately confirm their ability to predict future falls (Sun & Sosnoff 2018: 8-9).

> ***In the long term, such ambient sensing technology may provide an unsupervised, automated fall risk screening tool in a community and/or assisted living settings (Sun & Sosnoff 2018: 8).***

3.2.3 Interactive technology: video games, virtual and augmented reality

Interactive games using digital technologies can play a role in falls prevention by educating and increasing awareness of fall risks, and by engaging older people in physical activity designed to improve mobility and reduce the risk of falling. Game consoles and sensor devices such as *Nintendo Wii* and *Microsoft Kinect* are often used in this context. Virtual reality (VR) applications present simulated 3D interactive environments and can be used alone or to augment fall- preventing physical activity interventions (Hamm et al 2016).

A small but growing area of research is comparing the effectiveness of VR based training with traditional training methods. A recent Australian study (Phu et al 2019) compared the effects of virtual reality and traditional balance training on 195 participants with a history of falling. Both forms of training achieved comparable results on a range of standard balance and physical performance tests, indicating that VR can be an important training tool in falls management.

Multiple studies have identified that interactive games have a role to play as an adjunct to (rather than alternative to) existing falls prevention interventions. They have been found to motivate participation in physical activity interventions, in part because of their ability to provide feedback on performance (Hamm et al 2016).

3.2.4 Smartphones and Tablets

The technologies built into Smartphones can include inertia measurement units, sensors (accelerometer, gyroscope, GPS), camera, computing ability and display features, all of which offer potential in fall prediction diagnosis. Furthermore, the rapid growth of Smartphones and Tablets has made them increasingly affordable and accessible with significant potential to utilise video games, including those that are VR and AR enabled. Applied in combination with purpose-designed Apps they have a key role to play in preventing falls. and offer significant scope for engaging older people in falls prevention programs (Hamm et al 2016).

However, a recent systematic review concluded that Smartphone technology had yet to be validated as a fall prediction diagnostic tool - although two studies were identified that validated accuracy in balance and mobility tracking (Sun & Sosnoff 2018: 8 citing Roeing et al 2017 and Nishiguchi et al 2012).[35]

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[35] Roeing K, Hsieh K & Sosnoff J (2017) A systematic review of balance and fall risk assessments with mobile phone technology. *Arch Gerontol Geriatr.* 73: 222–6.

Nishiguchi S, Yamada M, Nagai K et al. (2012) Reliability and validity of gait analysis by android-based smartphone, *Telemedicine and e-Health*, 18(4):292–6.

3.3 Medication management

Paper-based medication brings multiple problems relating to duplicated information, conflicting information, illegible handwriting and lost faxes – all of which create the potential for errors and wastage of resources. Furthermore, medication is one of the multiple risk factors associated with falls, often because of side effects, such as, dizziness, or because of the interactive effect of polypharmacy (Coggins 2019).

By early May 2019, residential aged care providers had reported in excess of 112,000 incidents of substandard clinical care to the Royal Commission into Aged Care Quality and Safety. Of these, some 68,000 incidents involved medication mismanagement. Among the findings of the recent review of research by the Pharmaceutical Society of Australia were that 250,000 hospital admissions annually are a result of medication-related problems of which half are preventable. In relation to residential aged care, the review identified that -

- Over 90% of residents in aged-care facilities have at least one medication-related problem, with an average of 3.2 problems per person.
- As many as 80% are prescribed potentially inappropriate medicines (PSA 2019: 6, 14).

There is significant potential to improve quality and increase safety through purpose-designed medication management technology and around Australia, individual providers have begun to invest in such technology. With the appropriate infrastructure, standards and agreements that allow the exchange of digital data, this can also support consumers receiving care from multiple providers across multiple service sectors. However, this is one of the key challenges to a technology-enabled aged care system, as discussed in Section 4.3.

Case Study 3 (below) illustrates the importance of establishing cross-sector ecosystems that support information sharing across aged care, health care and pharmaceutical service provision. It exemplifies how one provider, Adelaide-based *Life Care,* has used technology to automate medication ordering and dispensing, and established digital communication that links their nursing and care staff, GPs and pharmacists, in the process reducing risks associated with human error in providing medication to their residents.

3.3.1 Case Study 3: Technology-enabled Medication Management at Life Care

In New Zealand, most aged care providers and many health care providers use the *Medi-Map* technology to manage medications. Evaluation of *Medi-Map* in New Zealand found a 22 per cent decrease in medication wastage over 12 months. Participating doctors identified improvements in the speed at which they could review records, chart medication and send or receive notifications. Feedback from nurses cited the freeing up of their time to care for patients as a result of the system's efficiencies. [36]

Medi-Map provides a cloud-based means to chart, store and share medication records and was developed by a New Zealand pharmacist working in collaboration with technology partners. It has been found to generate quality care benefits as well as resource efficiencies (through time-saving

[36] Case Study - Spark Digital (2017) Medi-Map - https://www.sparkdigital.co.nz/case-studies/medi-map/

automation and reduced medication errors and wastage). It's stock control and stock-taking software also supports detailed tracking of pharmaceuticals and automated re-ordering.

In 2017, Adelaide aged care provider *Life Care* became the first provider in Australia to adopt *Medi-Map,* which apart from its quality care outcomes, also overcomes the lack of interoperability (see Section 4.3) and sharing of health and aged care consumers' health needs and records by creating its own GP-aged care provider-pharmacist ecosystem. This involves Life Care's five residential facilities, a well-known Adelaide pharmacy chain and clients' GPs (with the latter controlling its operation, preparing prescriptions and updating these as needed onto *Medi-Map.)*

A number of similar products have been, and are being developed, including Telstra Health's *MedView* [37] - a national cloud-based platform that health professionals access to obtain information about their patient's medication history and provides advanced medications management capabilities. *MedView* has transmitted more than 2 billion prescription and dispensing records, involving in excess of 22,000 prescribes and 4,900 pharmacies nationally.

Life Care has given permission to the ACIITC to include this Case Study in this Literature Review.

3.4 CONTINENCE MANAGEMENT

Most assessments of continence in Australian residential aged care are undertaken manually by care staff (Fish & Traynor 2013: 35). This is labour-intensive, time-consuming and intrusive. They are also reliant on older people being able to communicate their toileting needs, which is not always possible when incontinence co-exists with dementia. Although technology has been found to hold promising potential for addressing all of these challenges, the evidence base remains *limited*.

There are very few systematic reviews of the effectiveness of technology-enabled continence management among older people. A systematic and grey literature review of published randomised controlled trials and quasi-experimental studies reporting effective continence service design for people living in the community concluded that technology *"… can potentially enhance current models of continence care."* (Wagg et al 2014: e104129). In particular, technologies that support telehealth and remote monitoring, and Internet-delivered treatments that include e-mail support, self-assessment tools and cognitive behavioural exercises were found to be effective. The authors also concluded that the increasing use of electronic health records could be expected to support diagnosis and evidence-based management and treatment (Wagg et al 2014: e104129).

Another major review was undertaken as part of the *Health Quality Ontario Technology Assessment Series*[38] Health Quality Ontario (2018) undertook a health technology assessment

[37] MedView (2019) MedView is powered by eRx Script Exchange, a wholly owned subsidiary of Fred IT Group - https://www.medview.com.au/

[38] In order to continuously improve the quality of health care in Ontario, the Ministry of Health and Long-Term Care established a health technology assessment mechanism to scientifically analyse evidence regarding health-related technologies and medical devices. This is reviewed by the Ontario Health Technology Advisory Committee, a group of evidence-based experts from across the province, and

to determine the clinical and cost-effectiveness of electronic monitoring systems designed to accurately track and report on urinary incontinence, in real-time, for residents of long-term care homes or geriatric hospital in-patients with complex conditions. These have the potential to enable clinical care staff reading the reports generated to individualise toileting times, adjust care routines, and select appropriate incontinence products.

However, *only one* study was identified that attempted to evaluate the effectiveness of an electronic monitoring system. During a 12-week trial, urinary continence assessment and management of older people were improved, with statistically significant outcomes involving reduced volume of urine voided into continence aids, reduced number of prescribed toileting visits, increased number of actual toilet visits, increased number of successful toileting events and increased adherence to urinary continence care plans by staff. The authors concluded that a suitably designed telemonitoring system combined with staff training can improve urinary continence care (Yu et al 2014).

With only a single, albeit positive, research study, the Health Quality Ontario Expert Panel concluded that it was *not* possible to be certain that electronic monitoring systems to assess incontinence are more successful in improving continence management than manual assessments of incontinence for people living in long term residential care or geriatric hospital in-patients requiring complex care. There were no cost-effectiveness or cost-utility studies of an electronic monitoring system to assess urinary incontinence identified, but the Panel noted that these have the *potential* to reduce costs to the health care system if the clinical evidence shows greater effectiveness than standard continence management, mainly because of the reduced amount of time required from personal support workers.

Fish and Traynor (2013) reviewed the small number of studies that have involved sensor-based 'smart' continence aids, used in combination with wireless monitoring. These record in continence patterns in real-time and automatically send this information to central data management systems. Each of these studies yielded positive findings, highlighting the *potential* for technology-enabled continence management (Fish & Traynor 2013: 35-39).

3.5 PAIN MANAGEMENT

As Smartphones become an increasing feature of daily life, it can be expected that the use of mobile health (mHealth) technology will increase, including for people living with chronic pain. These technologies include electronic pain diaries, digital pain assessment programs, Smartphone pain Apps, activity trackers and Internet-based therapies.

At this stage, research evaluating the effectiveness of health technologies focused on older people's pain management is scarce, but can be expected to grow**.** There are more studies associated with the population as a whole, and with specific illnesses known to be associated with pain, for example, cancer. Some of those studies will include older people, but they are not the focus of the research.

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research findings are published in a journal called the *Ontario Health Technology Assessment Series,* which is indexed in MEDLINE, EMBASE, and the Cochrane Library. See https://www.hqontario.ca/Evidence-to-Improve-Care/Health-Technology-Assessment

One integrative review focused on the use of digital health technology for managing older people's pain across care-settings, and from a field of 1,003 papers found only nine that met the inclusion criteria. The highest level of evidence was generated by three randomized controlled trials that demonstrated the feasibility of computer-based interactive or instructive video interventions. However, across the literature as a whole, there was limited evidence to support their use for reduction of pain intensity and interference (Bhattari & Phillips 2018).

There are a number of studies that focus on using technology to manage pain associated with a specific or chronic condition experienced by many older people, for example, arthritis. One systematic review identified 373 pain self-management Apps relevant to arthritic pain management and concluded that few offered a comprehensive pain self-management approach incorporating evidence-based strategies (Bhattarai et al 2018).

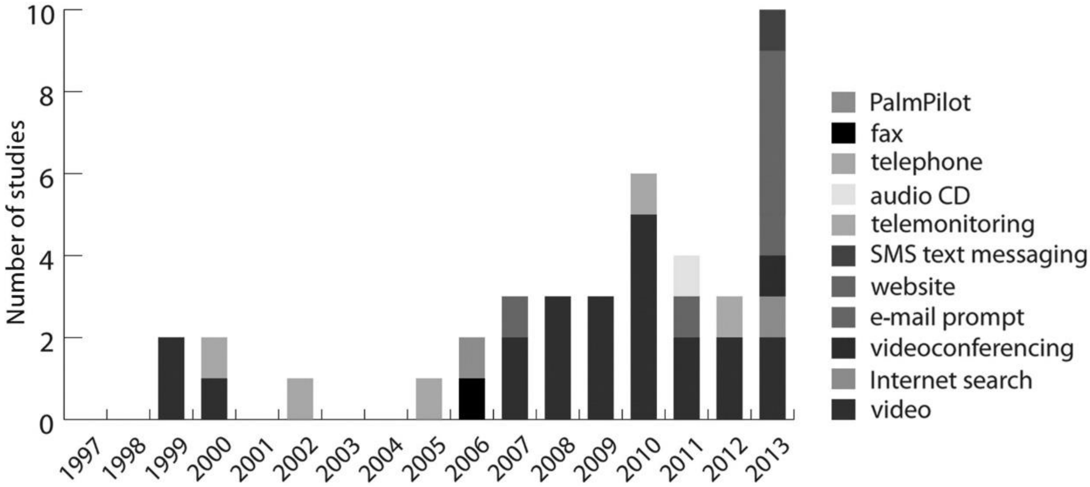
Another systematic review investigated empirical applications of mHealth technologies, particularly mHealth Apps, designed to support self-management of osteoarthritis. It too found a lack of research evidence on the effectiveness of mHealth apps focused on this condition. Most of the available Apps (60.9%) provided only educational information or instructions on activities and exercises known to be helpful in managing osteoarthritis-related pain and symptoms. Missing were evidence-based mHealth Apps that track and quantify pain and symptoms, and share the data collected with the person's clinicians (Choi et al 2017).

3.5.1 Technology supporting pain management and end of life care

The use of ICTs in End of Life (EOL) care is a small but growing field of research (Ostherr et al 2016). A recent systematic review filled a gap in available research by identifying the uses and effectiveness of ICTs in EOL care. From the 38 relevant articles identified, eleven types of technology were identified: video, website, telephone, videoconferencing, e-mail, telemonitoring, Internet search, compact disc, fax, PalmPilot, and short message service (SMS) text messaging (see Figure 3 below).

This review also documented the significant growth in research on ICTs in EOL care in recent years. Between 1997–2009, 16 studies that met the study's inclusion criteria had been published, averaging less than one study per year. In contrast, 22 studies (58% of included studies) were published between 2010 and 2013, averaging five studies per year, with nine of the studies (24%) published in 2013 alone (Ostherr et al 2016: 410). The Figure below plots this trend against the 11 technologies identified as supporting EOL care.

FIGURE 4: CHANGING USE OF TECHNOLOGY IN END OF LIFE CARE



Source: Ostherr et al 2016, Figure 2, page 416

On average, each intervention used ICTs for at least two purposes, with 61% of studies using technology to provide information and/or education, and 53% of studies using technology as a decision aid. Approximately 24% of the studies reviewed used ICTs to relieve physical symptom distress (Ostherr et al 2016: 416).

Unsurprisingly, the review identified the increasing use of Internet-based interventions, in part reflecting increased access in developed countries to high-speed broadband Internet (Ostherr et al 2016: 416). Noting the ethical and logistic sensitivities associated with conducting research on patients nearing EOL, and the consequent need for researchers to develop innovative techniques that may not always conform to sound methodological standards, the authors concluded that technology-enabled end of life care is a rapidly growing area of enquiry, with a *maturing* evidence base.

> ***The results show that ICT use in EOL care is an emergent and expanding area of research, with a variety of ICT tools undergoing rigorous evaluation. Although the field is young, almost half (45%) of the included studies were randomized, controlled trials—the gold standard in evidence-based medicine—and therefore, the evidence base for the field shows promising signs of maturation. However, many of the studies compared the effectiveness of the ICT intervention to "usual care," with fewer studies comparing effectiveness among different ICTs (Ostherr et al 2016: 410).***

3.5.2 Technology supporting pain management for people with dementia

Technology can assist in the identification of pain among people with moderate to severe dementia by compensating for individual inability to self-report pain and human error in assessing their pain because of reliance on subjective decision-making. One study reported an evaluation of the electronic pain assessment tool (ePAT)[39] – a point-of-care App that

[39] Hughes J, Hoti K & Atee MAW (2016) Electronic Pain Assessment Technologies (ePAT) Pty Ltd, assignee. A pain assessment method and system, World Intellectual Property Organization (WIPO), Patent 025989, 2016-02-25.

utilizes facial recognition technology to detect facial micro-expressions indicative of pain. The ePAT also records the presence of pain-related behaviours under five additional domains - Voice, Movement, Behaviour, Activity, and Body (Mustafa et al 2017). It was developed by a research team at Curtin University, Western Australia, in collaboration with nViso SA which is located at the Swiss Federal Institute of Technology in Lausanne.

The ePAT's psychometric properties were evaluated against the widely recognised *Abbey Pain Scale* which was also designed to measure pain for people living with dementia. Based on 350 paired pain assessments, the ePAT performed well in relation to concurrent validity, discriminant validity, inter-rater reliability and internal consistency and demonstrated a strong correlation with the Abbey Pain Scale. Furthermore, ePAT's automated facial expression assessment was found to provide 'objective and reproducible evidence of the presence of pain' and to *automatically* calculate a pain severity score.

3.6 SUPPORTING PEOPLE WITH DEMENTIA

Technology has an increasing role to play in supporting people *living with dementia* in multiple ways, including:

1) *safety-related devices* (especially tracking or way finding and cooking safety).

2) *Memory aids*.

3) Technology designed to *prevent social isolation* (including by the use of companion robots).

4) Technology designed to *promote wellbeing* (a growing number of Apps are being developed specifically with this goal in mind).

5) *Clinical care support* of various kinds (for example, *music therapy* and *symptom monitoring*). The literature identifies a growing acceptance by service providers of these technologies and of *videoconferencing for diagnosis and monitoring.* Reliable findings have identified the role of video telemedicine being used for neurocognitive testing and neurological examination (Bossen et al 2015: 4-5).

6) An increasing number of aged care providers are incorporating *virtual reality* technology into their dementia-specific services providing a range of virtual experiences tailored to past experiences (such as, countries visited) with outcomes that include mood, wellbeing and engagement enhancement. See Section 3.6.3 for further discussion.

7) Another emerging field is the '*gamification of therapy*', that is, the use of video games as therapeutic tools (Ienca et al 2017; Marasinghe et al 2016; Bossen et al 2015; Evans et al 2015). This can be used as part of virtual reality technology applications in the care setting – a good Australian example being the **VDE™** training tool also described below in Section 3.6.3.

As with many technologies, these benefits can be shared more widely with all older people (whether they are living in residential care or in the community), and their positive impact extends to informal carers, particularly by lessening anxiety about the safety of the person being supported by them (Marasinghe et al 2016).

However, despite the potential offered by rapidly developing technologies, research assessing their clinical effectiveness, and the translation of technological knowledge into dementia care, continue to be slow in growth (Moyle 2019; Ienca et al 2017). The research literature on the role technology can play in supporting people with dementia is as notable for its gaps as it is for its contribution to the evidence base.

3.6.1 Most common dementia-supporting Intelligent Assistive Technologies

One very useful systematic review provides a comprehensive overview and developed an *Index of Intelligent Assistive Technologies* (that is, with their own computational ability - eg wearables, personal care robots, smart homes, integrated sensors systems, mobile platforms, Apps) that can be applied in dementia care. The Index was designed to facilitate the translation of medical engineering research into clinical practice (Ienca et al 2017). Their review process identified **539** Intelligent Assistive Technologies with existing or potential application to dementia care, the largest of which involved *ambient assisted living technologies* (and within this, the ongoing development of the Internet of Things), while the largest period of increase for all these technologies occurred from **2014 onwards** (Ienca et al 2017: 1306, 1332).

The second-largest group of technologies involved *personal care robots,* reflecting recent and rapid advancements in medical robotics. The most reviewed type of robot was the domestic service robot, while an increasing proportion of socially assistive robots was evident, that is, robots designed to assist with the emotional and social needs of older people (Ienca et al 2017: 1332).

Hand-held multimedia devices (eg Smartphones, tablets and other mobile devices) were identified as co-evolving with a rapidly growing *digital ecosystem of health-focused Apps and other software applications* designed to assist people living with dementia. A recent and growing trend was identified in *dementia-specific Wearable devices*, and the use of *virtual reality* (VR) and *augmented reality* (AR) systems (Ienca et al 2017: 1332).

MOST COMMON APPLICATIONS OF DEMENTIA-SUPPORTING INTELLIGENT ASSISTIVE TECHNOLOGIES

In reviewing the specific **application** of these technologies to dementia care, the review found the following trends:

- the most common application involved supporting older people with dementia in the *completion of Activities of Daily Living*, and in doing so, supporting their independent living capacity.
- The second most common involved *monitoring*.
- The third involved *physical assistants* (compensating for motor and mobility limitations) and *cognitive assistants*, that is, intelligent devices capable of supporting or augmenting cognitive functions, for example, memory aids.
- *Emotional support and assistance* emerged as a smaller but rapidly developing segment of the application of Intelligent Assistive Technologies (Ienca et al 2017: 1333).

3.6.2 Clinical validation and Co-design of these Intelligent Assistive Technologies

Analysis by Ienca et al (2017) of the clinical validation of Intelligent Assistive Technologies for dementia found that *slightly less than half* involved clinical trials with human subjects, most of which were conducted with *small sample sizes* (< 20 participants). The randomized-controlled design was reported in only *1.1%* of clinical trials, that is three of the identified studies. Only *40.1%* involved *co-design* with older people, but this trend had been increasing in recent years and was expected to grow (Ienca et al 2017: 1334).

Earlier reviews also identified the lack of technologies developed through *co-design* with people with dementia as a major gap in the evidence base (Evans et al 2014: 415; Bossen et al 2015: 9).

> ***The range of technologies currently available illustrates a need for more context-aware and intelligent software to be developed through extensive user testing and evaluation. This is essential as, without design input from both individuals with dementia and their caregivers, acceptance is low (Evans et al 2014: 415).***

3.6.3 Virtual reality as a dementia-specific training tool

There has been a recent but growing application of virtual reality (VR) technology to the care of older people living with dementia. At this stage, there is *limited* underpinning research evidence, but a small number of evaluations indicate its promise as an *educational* tool (Slater et al 2017; Adefila et al 2016; Doube & McGuire 2016; Beville 2014, 2002).

Three well known VR training programs - *myShoes* (Adefila et al. 2016), the *Virtual Dementia Experience™ (VDE™)* (Alzheimer's Australia Victoria 2014) and the *Virtual Dementia Tour® (VDT®)* (Beville 2014, 2002) each apply virtual reality to increase dementia awareness from the perspective of the person with dementia, enabling participants to experience the world as they experience it. Each has been independently evaluated, with positive impacts identified for the sample groups involved, but more robust, large scale evidence is still required (Slater et al 2017: 19).

THE VIRTUAL DEMENTIA TOUR ®

Developed by American not-for-profit education provider *Second Wind Dreams,* the ***Virtual Dementia Tour ®*** is used for workforce development in more than 20 countries, including Australia. For example, it has been undertaken by more than 2,500 staff employed by Churches of Christ in Queensland since July 2017, with a positive impact reported on participants' understanding of dementia.[40]

The ***VDT®*** aims to replicate moderate dementia, including its distortion of cognitive and sensory functions. While enhancing empathy, this experience has been found to generate a range of negative emotional response (such as, fear, helplessness, frustration) in participants.

[40] Cheu S (2019) Virtual experience improves care of residents with dementia, *Australian Ageing Agenda,* May 1st 2019

Evaluations have identified the increased understanding of the lived experience of dementia (Slater et al 2017; Beville 2002, 2014).

However, one researcher has raised **ethical concerns** about the virtual experience of the range of negative emotions involved and its promotion to all carers – including family caregivers (Merizzi 2018). Apart from providing 'an abusive reality' where participants have been found to experience increased levels of blood pressure and anxiety, frustration with not being able to complete tasks, and agitation when requests for assistance were ignored by the researcher (citing Beville 2002), the negative focus of the experience is seen as providing only a narrow view of living with dementia.

… it does not consider the persons' ability to adapt to life experiences and people's resilience in terms of experiencing love, attachment, enjoyment and beauty. In fact, the VDT® proposes a very narrow way of experiencing dementia and this can easily increase generalisation, pessimistic views and stigma about dementia (Merizzi 2018: 150).

Merizzi also raises methodological concerns about the promotion of the ***VDT®*** to all carers because of the lack of scientific evidence of its validity when extended to a broader population, being based on a single study in which only professional carers participated (Merizzi 2018: 150). For both of these reasons, she suggests caution in using this program.

The VDE™

The **VDE™** is a multi-award winning Australian based program created by Alzheimer's Australia Victoria (AAV) [41] in collaboration with Melbourne game developers, *Opaque Multimedia,* and with carers, people with dementia and AAV's educators. It uses virtual reality gaming technology to promote empathy for and understanding of issues faced by people living with dementia. It aims to increase knowledge about person-centred dementia care, to assess the impact of environmental design on people with dementia and assist carers to gain insight about their care provision practice.

In an evaluation commissioned by Alzheimer's Australia Victoria, Doube and McGuire (2016) reported that the VDE™ program's experiential learning achieved statistically significant increases in its intended empathic understanding and knowledge compared to usual classroom training. However, this is a single study and more robust evidence is required (Slater et al 2017: 19).

[41] See https://www.dementia.org.au/information/resources/technology/virtual-dementia-experience

MYSHOES

The **myShoes** training program (Adefila et al. 2016) shares the learning and empathy-enhancing goals of the VDE and VDT initiatives. It uses a stereoscopic head-mounted device and gaming technology to immerse the wearer into an avatar body in order to simulate the reality of the dementia experience. The session concludes with a debriefing exercise where learning and other outcomes are analysed.

Evaluation of the program (Adefila et al 2016) with 55 care professionals identified that its intended outcomes were realised, with increased understanding, empathy and compassion at a level that was statistically significant. As with the evaluation by Doube and McGuire (2016), this is a small size study but its findings are positive and encouraging.

Case Study 4: Virtual reality, gamification and research - Sea Hero Quest

Sea Hero Quest provides an example of an effective partnership between technology and ageing experts.[42] Designed by game studio Glitchers in 2016, in association with Alzheimer's Research UK, University College London and the University of East Anglia, this virtual reality game measures spatial navigation ability. The data generated every two minutes by ***Sea Hero Quest*** players has been quantified as equating to five hours of traditional laboratory research (Bozorgzadeh 2019). This is an important contribution to knowledge about dementia.

Recent research used the Smartphone App version to monitor how more than 27,000 players aged between 50 and 75, with or without a genetic predisposition to Alzheimer's, navigated a virtual world, using their thumbs to move a boat through a series of maritime mazes. The spatial navigation big data from the playing of ***Sea Hero Quest*** game was analysed to yield a benchmark distinguishing low-risk people from those who were high risk because of their genetic profile (based on the APOE gene). The researchers concluded that high-risk preclinical individuals could be 'reliably distinguished' from low-risk participants using big-data spatial navigation benchmarks – despite being undistinguishable based on neuropsychological episodic memory tests (Coughlan et al 2019).

3.6.4 Emerging technological interventions to predict dementia

SENSOR-BASED GAIT ANALYSIS

Gait is emerging as a potential diagnostic tool for cognitive decline, being one of a number of clinical biomarkers that include changes in walking characteristics and behaviours, and that are known to be important in the detection of early indicators of dementia (Mc Ardle et al 2018).

[42] See https://www.alzheimersresearchuk.org/our-research/what-we-do/sea-hero-quest/

A pilot study from the UK's Newcastle University used small wearable sensors that measured gait during everyday tasks and found that these yielded comprehensive data regarding walking behaviour and pattern, and gait characteristics relating to the pace, timing, variability, and asymmetry of walking. The researchers concluded that this application of sensor technology holds potential for 'affordable, multi-centre and home-based monitoring' bringing benefits for individuals as well as service systems (Mc Ardle et al 2018).

ALGORITHMS TO PREDICT DEMENTIA

A new algorithm-driven model developed at MIT has been found to predict if people at risk of developing Alzheimer's Disease will experience clinically significant cognitive decline by predicting their cognition test scores up to two years in the future. MIT researchers analysed the world's largest Alzheimer's disease clinical trial dataset – the *Alzheimer's Disease Neuroimaging Initiative* – which holds data from 1,700 participants, with and without Alzheimer's, recorded during six-monthly visits to doctors over a 10 year period. Data include cognitive assessment testing, MRI scans, demographic and genetic profile information (MIT News 2019).[43]

The researchers used the data to train a population model, personalised for individual participants, that have been found to outperform a number of traditional machine-learning approaches applied to clinical data. They also applied a "metalearning" scheme that learned to automatically choose which type of model, population or personalised, was most appropriate for any given participant at any given time. This was the first time metalearning had been applied to track cognitive decline due to Alzheimer's Disease (AD). The model can also be generalised to predict various metrics for Alzheimer's and other diseases (Rudovic et al 2019).

> ***This automated approach for forecasting of cognitive changes in AD could augment and assist clinicians by providing them with intelligent data summarization and decision support tools for early identification of at-risk subjects and construction of informative clinical trials (Rudovic et al 2019: 14).***

[43] MIT News (2019) *Model predicts cognitive decline due to Alzheimer's, up to two years out.* http://news.mit.edu/2019/model-predicts-alzheimers-decline-0802

4. BARRIERS AND CHALLENGES TO THE ADOPTION OF TECHNOLOGY-ENHANCED AGEING AND AGED CARE

There are multiple potential barriers that affect the adoption of technology and its integration into core aged care service design and delivery. These occur at different levels – from individual consumers and their supporters, to aged care and health providers, to organisations and systems. However, almost all of the available literature is focused on individual readiness while the remaining levels are rarely investigated.

A project undertaken on behalf of ACOLA (Australian Council of Learned Academies) in 2014 did, however, investigate barriers to technology uptake at all of these levels, finding impediments arising from the following:

- Technology being too difficult to use, to integrate into living environments and daily living patterns, or not suiting end-user needs.
- Insufficient incentives or subsidies to encourage health practitioners to adopt technologies that could assist in providing care.
- Lack of leadership and capacity to navigate the silos posed by federal and state governments, technology developers, health practitioners, care providers, policymakers and non-government organisations.
- Lack of champions to influence policy and organisational decisions regarding the adoption of assistive technologies (Tegart et al 2014: 4-5).

Please refer to the *Technology Roadmap for Aged Care* – Destination 5: A technology-literate and enabled workforce and Destination 1: Technology-enabled operational, business and communication systems and Destination 3: Technology-enhanced information and access to care for discussion of the different levels of technology readiness.

4.1 INDIVIDUAL READINESS

Australian consumers are notable for being fast adopters of new technology (ACMA 2015). However, uptake of technologies by older Australians to support better health and independent living does not necessarily reflect this trend. Regardless of the extent to which technological innovation is fit for purpose, is well designed, or is likely to significantly enhance health, wellbeing or independence, its adoption requires its end users to be reasonably 'tech-savvy' – that is, with technological literacy and associated with this, confidence in using technology. For older people who have not grown up with ICTs, this can present challenges which must be addressed for them. The failure by technology developers to not include older people as co-designers of technologies intended for them also affects uptake rates (Winn & Nisbet 2015: 4).

The ***Australian Digital Inclusion Index* (ADII)** was first published in 2016 and measures three central dimensions of digital inclusion: Access, Affordability, and Digital Ability. The 2019 ADII showed an overall gain of 7.9 points in Australia's total digital inclusion score (61.9) and with improvements evident across all three dimensions of digital inclusion – Access, Affordability and Digital Ability. This increase occurred in every state and territory. However, the *Digital Divide* continued with several groups continuing to record low digital inclusion scores, although each of these also registering some improvement in the past year (Barraket et al 2019: 5).

People on low incomes were the least digitally included group, while those aged 65+ continued to be the *least included age group* and were the third least digitally included of all groups. The ADII score for this age group at 48.0 was 19.5 points lower than the most digitally included age group (people aged 25-34 years).

However, for the first time, this Divide narrowed slightly, down from 20.5 points in 2018. People aged 65+ had improved their overall score by 2.1 points. The tenth least digitally included was people aged 50 to 64 years with a score of 60.4. They too had improved their score from last year. The ongoing Divide between metropolitan and rural Australia persisted but had narrowed due to the improved access enabled by the NBN (Barraket et al 2019: 6-7).

The Office of the eSafety Commissioner (2018) commissioned research into how older Australians perceive and use digital devices and the internet. This research has been undertaken to inform the development of the *Be Connected* program to provide resources and support training to increase the confidence, skills and online safety of older Australians. The research involved a national survey of 3,600 older Australians aged 50 years and over and focus groups with 26 respondents who were identified as having no to low digital literacy.

The findings are presented in report format as well as three useful infographics focused on Attitudes and Motivation, Confidence and Fear of going online.[44] Older Australians aged 50-69 were found to be significantly more engaged with Internet usage than their older counterparts who expressed a lack of trust, confidence, skills and perceived relevance for online usage. The desire to use the Internet was found to decrease with age – highlighting the importance of disaggregating findings beyond the large, and not very useful categorisation of 65 and over.

Research findings identify that older people will use technology if it is *affordable, accessible* (information and services associated with the technology are available) and *easy to use*. Support from family is critical for adoption. See also discussion of enablers in Section 2.2.1.) Barriers to usage include cognitive (memory and processing speed), visual, auditory and motor control ability, attitudinal, privacy concerns, safety and security, and concerns that

[44] See https://esafety.gov.au/about-the-office/research-library/attitudes-and-motivations-of-older-australians; https://esafety.gov.au/about-the-office/research-library/older-australians-and-digital-confidence; https://esafety.gov.au/about-the-office/research-library/older-australians-and-the-fear-of-technology

humans will be replaced entirely by technology (Mostaghel 2016: 4897 citing multiple researchers: Peek et al 2014: 241 citing multiple studies). However, older people's willingness to use technology will also be influenced by their perceived need for that technology which is the most frequently identified factor in adoption (Peek et al 2014: 242).

Obviously, the many factors influencing or inhibiting uptake will *interact*, requiring older people to trade-off inhibitors (such as, cost of technology) against motivators (such as, enhanced independence) and will *vary* from one individual to another, underscoring the importance of these two principles: i) *tailoring* technology to individual need and circumstance; and ii) *co-design* with end-users. The table below summarises trends in the research literature findings on these different sets of factors.

TABLE 2: FACTORS ENCOURAGING AND INHIBITING ADOPTION OF TECHNOLOGY

Factors encouraging adoption	Factors inhibiting adoption
Expected benefits from using technology	**Concerns about technology**
• Increased safety	• High cost
• Perceived usefulness	• Privacy concerns (e.g. video monitoring)
• Increased independence	• Forgetting or losing technology
• Reduced burden on significant others	• Burdening significant others (e.g. needing assistance to use technology)
Need for technology	• False alarms
• Perceived need for technology	• Ineffectiveness (in addressing need)
• Subjective health status	• Obtrusiveness (linked to stigma, see below)
• Technology will enhance safety & security	• Stigmatisation as 'old' or 'ill' (design issue
	• Impracticality
	• Low ease of use
	• Negative effect on health
	• No control over technology (e.g. to switch on/off)
	• Difficult to access
Individual characteristics	**Individual characteristics**
• Desire to age in place (attachment to home, local neighbourhood)	• Physiological limitations (e.g. limited manual dexterity, sensory deterioration)
• Confidence to use technology	• Cognitive limitations
• Technological literacy	
Social influences	**Social influences**
• Family and friends encouraging	• Family and friends discouraging
• Professional service providers encouraging	• Professional service providers not encouraging
• Use by peers	• Absence of peer role models for usage

Sources: Peek et al 2014: 241; Mostaghel 2016: 4897; Vichitvanichphong et al 2014: 2713; Sanders et al 2012: 10

4.2 Ethical issues

The inclusion of technology in the provision of services to older people requires an assessment of ethical issues. Unfortunately, these tend to be identified once a product has become available, again because much of the research is focused on technology feasibility studies and far less on its impact on older people. A focus on ethical issues associated with technologies that can support older people is largely absent in the research literature (Zwijsen et al 2011). Where such studies have been undertaken, the ethical challenges receiving most focused attention involve concerns about *safety, security* and *privacy* (Novitzky et al 2015: 758). This has become particularly evident as video surveillance becomes part of everyday life.

As discussed in this literature review, a number of studies based on feedback from end-users identify concerns about loss of privacy from monitoring technologies, with video-based monitoring repeatedly perceived as invasive and undesirable – see Section 2.4.1. While these studies are not designed to identify ethical issues, this very clear feedback from consumers about the importance of privacy is also relevant from an ethical perspective.

It is also evident from the literature that end-users who are able to do so, make trade-off decisions about the potentially intrusive nature of monitoring technologies – preferring a loss of some privacy to losing the ability to live independently at home. However, for those who are unable to make such a decision, and to provide informed consent, the ethical issues are more challenging.

4.3 Organisational and system readiness

Technology has a significant role to play in the provision of care as well as in the underpinning operational and business systems that support care providing organisations. However, there is very little research on technology maturity at the organisational level in Australia or the aged care system in which those organisations are located.

The ACIITC implemented the *Aged Care Technology Benchmark Survey* in 2014 to identify the extent to which the aged care sector was engaging with technology in its operations, business processes and analytics, and in its delivery of care, particularly consumer-directed care. The Survey applied the *MIT Digital Maturity Matrix*, which was developed from extensive research globally across major companies and forms part of a longitudinal study involving 50 companies. The Matrix reflects where agencies are placed with respect to digital transformation. Findings from the survey highlighted the relatively *low level of sector readiness* for technology in Australia, particularly in relation to the provision of care:

- About 75 per cent of the sector was interested in Digital Disruption but was not engaged in its adoption to a level comparable with this degree of interest.
- There were very few Technology Leaders or Champions from the sector.
- There was little integration of technologies within aged care organisations.
- There was very low integration of technological requirements across the health and aged care sectors (e.g. via electronic health records).

- The sector had a long way to go in incorporating technology into Consumer Directed Care and other aspects of aged care reform (Livingstone 2014).

The ***Technology Roadmap for Aged Care*** recommended that the *Technological Maturity Assessment* survey be repeated every three years, building on the 2014 benchmark established by the above and extending the survey beyond community care to the sector as a whole. It recommended that such a review focus on technology-enabled care services, and on technology-enabled business and operational systems - quantifying structural arrangements, underpinning systems and capacity for interoperability. *(Refer to Destination 1 of the Roadmap, Issue 2, page 21).*

More recent Australian research surveyed all NSW residential aged care facilities (n = 876) to measure IT sophistication via IT capabilities, extent of IT use and IT integration in two domains, resident care and clinical support. IT sophistication was highest in IT capabilities and integration in resident care and was lowest in clinical support. Other findings included the following:

- The *highest* IT sophistication levels were found in the not-for-profit sector in all IT sophistication dimensions in resident care and the lowest in the for-profit sector, with significant differences between both sectors.
- Only 26.0% of organisations used portable computing devices such as laptops, tablets, and Smartphones.
- Only 25.0% of the responding organisations had integration of resident care systems with external entities including hospitals.
- 57.0% of the facilities reporting had no IT personnel in their workforce (Alexander et al 2019).

Research in the USA with long term aged care facilities has identified a number of predictors of IT sophistication ($p<.001$) including a) resident access to technology and b) residents or their supporters' use of electronic health records and personal health records. These findings were based on a sample of 815 nursing home leaders from almost every US state (Powell, Alexander et al 2019).

Residential aged care providers can benefit from the additional knowledge and clinical support brought by ICTs and in particular, from electronic health records - EHRs (Zhang, Yu & Shen 2012: 690). The number of studies focused on the contribution of EHRs is growing, with most identifying *multiple benefits* including efficient data entry, distribution, storage and retrieval; easy and quick data entry and distribution; convenient data storage; quick data retrieval; ease of access to aged care EHR; more information to better understand residents' needs and to support workforce development; more holistic information about residents, improved monitoring of care and quality of care; better decision making; more time to spend with residents because of time savings; better communication between staff and residents;

enhanced information management for the organisation; improved quality of nursing documentation; and a better work environment (Zhang, Yu & Shen 2011: 694-700).

However, the sharing of EHRs within the aged care sector and between this sector and the health sector remains under-developed, as does the research evidence base exploring the sharing of consumer data between these two sectors who play a critical, but highly separated, role in the health and wellbeing of older Australians.

One of the five Destinations structuring the 2016 *Technology Roadmap for Aged Care* – ***Destination 1: Technology-enabled operational, business and communication systems*** - identified that the shift to a consumer-directed aged care market model demands greater flexibility from service providers in responding to individual consumer demand and new business models to accommodate changes in financial management, service design, data collection and analytics. It argued that technology has a critical role to play in managing these changes, and that it will determine how successfully aged care organisations respond to a reformed aged care system. The advantages of technology-enabled and enhanced business systems include being able to monitor consumers, the workforce and their patterns of interaction, to better plan how that interaction occurs, and the resources required, supported by different automated processes and communication across a range of devices and contexts. It noted the significant variation in capacity to utilise intelligent business and operational systems, but ta growing number of aged care organisations are providing leadership for the sector as a whole.

The Roadmap also identified the next level of progress as requiring an operating environment characterised by seamless interconnection between devices, datasets, services, consumers and other stakeholders (e.g. government, health care providers, and disability providers). This will require the aged care sector to apply agreed standards and protocols that define precisely the interfaces between different components, enabling a range of combinations and ensuring interoperability. [45]. Such a shift is also being driven by broader technological changes involving increasingly connected digital devices and delivery via Cloud systems, the growing digitisation of health and aged care records, and the automation of a range of clinical and operational processes. In turn, these changes demand a more collaborative approach between aged care providers, end-users, vendors, developers and other key stakeholders. (Refer to Destination 1 of the Roadmap pp 18-19).

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[45] That is, the ability to communicate, access and exchange data without needing identical IT systems and products to do so

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