Australia's National
Science Agency

DACS: Smarter Safer Homes to Support Older People Living in Their Own Homes Through Enhanced Care Models

Final report on the findings of the randomised control trial.

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September, 2022

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1 Executive Summary

This report outlines the research trial, and final outcomes, of the Dementia and Aged Care Services (DACS) trial: *Smarter Safer Homes to support older people living in their own homes through enhanced models of care.*

This trial was an unblinded, randomised control trial, for people 65 years and over who were receiving community based aged care services. The study recruited participants with 97 participants receiving usual care only (control group) and 98 receiving the smart home technology (intervention group), in addition to their usual care. Participants were recruited via their aged care service provider with three partner providers involved: Anglicare Southern Queensland, integratedLiving Australia, and All About Living. All participants were either receiving services through the Commonwealth Home Support Programme or a Home Care Package.

The aim of this study was to validate the smarter safer home technology to support older community members living independently at home. To do this the primary outcome measure used was the social care-related quality of life. Secondary outcome measures included: health-related quality of life; functional independence; depression levels; health service utilisation; changes in service design, adoption and aged care service provider experiences; user experience among study participants; and care giver burden.

The overall outcome of this research was that for older adults with Home Care Packages, the smarter safer home intervention benefited their social care related quality of life, although there were no benefits observed against the secondary outcomes. However, the intervention did contribute to the intervention group staying independently in their own home for longer.

2 Introduction

Globally, the population is ageing with 703 million persons aged 65 years or over as of 2019 (United Nations, 2019). This is projected to double to 1.5 billion by 2050 with life expectancy on average expected to increase by an additional 19 years due to improved nutrition and healthcare. In Australia, over 20 years (1999-2019), the proportion of people aged 65 and over increased from 12.3% to 15.9%. The number of people living to 85 years and over increased by 117.1% (Australian Bureau of Statistics, 2020).

The Royal Commission into Aged Care Quality and Safety highlighted that one of the key measures of success for the future aged care system will be that every older person can access the care[i] they need, of an appropriate type, when they need it (Commonwealth of Australia, 2021). Australia's changing demographics influence the demand for, as well as our ability to provide, aged care. These changing demographics mean a decline in people of working age compared to those over 65. This decline has implications for the financing of the aged care sector and for the aged care workforce (*Royal Commission into Aged Care Quality and Safety - Final Report - Executive Summary*, 2021). Supporting the current care needs of the ageing population is already a challenge but supporting the future needs of this population will continue to increase the challenge. The Australian Government, in 2017-18, supported 77% of the 1.2 million older adults with community care packages or other community support services (Australian Institute of Health and Welfare, 2021).

Recognising the preferences of older Australians to age in their chosen home environment (Australian Institute of Health and Welfare, 2013) and the challenges in meeting the needs of an ageing population, CSIRO, in 2012, started work on innovative solutions to address these issues. CSIRO was one of the first to develop an innovative and consumer driven smart home technology, the Smarter Safer Homes (SSH) platform, to support older people living independently (Zhang et al., 2013). The SSH platform was an output of consultations with aged care service providers (ACSP) who contributed to the early designs of the platform along with expert scientific knowledge from CSIRO.

The platform took advantage of the rapid emergence of wireless home sensors and mobile devices for home monitoring and management of a variety of health-related conditions. The SSH platform was developed to assess functional aspects of human conditions such as activities of daily living (ADL) along with having the ability to collect information wirelessly on specific biometric information such as body temperature and blood pressure levels. Creating an original, and reliable, analytic that determines individualized functional activity trends within a home setting, was the major output of numerous trials conducted on the SSH platform. This analytic was able to provide information to the older person living in the home, the older person's family members/family carers, and the ACSP.

The initial development of the platform was followed by pilot trials that researched different aspects of the platform. These trials included multiple partners in different locations around Australia. Each time a trial was conducted, improvements and adjustments were made to the platform and a greater understanding of the uses for service providers and families/care figures

was gained. Please refer to Table 1 for an outline of the CSIRO research trials that have used the SSH platform to date.

Table 1. CSIRO research trials using the SSH platform.

Year	Research Activity	Recruitment number
2013	Armidale – Feasibility	8 recruits
2014	Melbourne – Usability for nursing services	6 recruits
2015	Sunshine Coast – Usability for family and carer	10 recruits
2016	Newcastle – Usability for dementia patients	10 recruits
2018	Brisbane – CSIRO OADL evaluation	25 recruits
2019	Brisbane – Dementia Aged Care Services Trial (DACS)	195 recruits
2020	Commonwealth Home Services Programme Trial (CHSP)	20 recruits

The Dementia Aged Care Services Trial (DACS) commenced in 2019 and was the largest trial evaluation of the SSH platform. The aim of the study was to validate the capacity of the SSH platform to enable older people to self-manage and ACSPs to support their clients to live functionally and independently in their own homes for as long as possible. This trial aimed to recruit 200 people based in the community and was funded by the National Aged Care Community Grants, The Australian Department of Health. At the time of commencement in 2019, the DACS trial was the only, large scale, Australian study using a smart home system to monitor function in older adults. Collectively the SSH technology trials have demonstrated the capability of technology enhanced care models to:

- Provide additional information and insights to care providers about how a client is managing at home.
- Allow providers to identify functional decline (which may not have otherwise been evident without the monitoring).
- Implement care strategies earlier than face-to-face visits allow.
- Augment the current model of in-home service provision with remote monitoring via in-home sensor systems.

- Allow for more regular (low touch) monitoring of clients to be delivered at scale, compared to the current model of face-to-face visits only (which are more infrequent than daily visual monitoring via a platform).
- Provide monitoring at distance and from a distance.
- Provide a sense of security and confidence to all users.
- Provide a basis for future service models using technology in aged care.

3 Smarter Safer Homes Solution

The SSH platform collects data from an individual's home via sensors to provide daily updates to the associated ACSP about how a client is currently functioning in their home environment. The platform includes a sensor-based in-home monitoring system (data collection), a cloud computing server (data analyses), and a client module (data presentation) with a tablet app, a family portal, and a service provider portal. Figure 1 shows the overview of the SSH platform.

Figure 1. Smarter Safer Homes overview

3.1 Sensor Data

The SSH platform includes environmental sensors and sensor networks that can monitor the physical environment within the home. All in-home raw sensor data is transferred to an Internet of Things (IoT) router and then collected directly to a secure web server where all sensor data is

gathered and analysed. It is then made available to those with authorised permission to access the analysed data.

The data gathered through the in-home sensors are categorised into ADL domains as shown in Table 2. It shows the spread of sensors installed in SSH homes and provides a description of the SSH sensors deployed and where they are installed in the home (Table 3).

Table 2. The mapping of sensors to daily living activity domains.

DAILY LIVING ACTIVITIES	SENSOR TYPE	LOCATION
Meal Preparation	Motion sensor Electrical power sensor Accelerometers	Dining room Kitchen
Dressing	Motion sensor Accelerometer	Bedroom (Wardrobe)
Hygiene	Motion sensor Humidity sensor Temperature sensor	Bathroom
Mobility / Indoor Walking	Motion sensor	All rooms
Transfer / Sit-stand transition times	Pressure sensor Motion sensor	All rooms
Sleep	Sleep Sensor	Bedroom
Social Score	Front Door Sensors	Front Door

Table 3. Description of SSH sensors deployed, the data gathered and where these sensors were installed.

	Motion Sensor	Incidents of motion within 5 metres of install	Corner in all rooms
	Light Sensor	The level of lights in a room	Corner in all rooms
	Temperature Sensor	Measuring between -10 ~ 50 °C	Corner in all rooms
	Humidity Sensor	Monitor humidity from 0% to 100%	Corner in all rooms.
	Vibration Sensor	Reporting event-based vibrations	Corner in all rooms
	Power Sensor	Monitor power usages of appliances	Wall outlets
	Sleep Sensor	Heart rate variability, Sleep, Movement	Under the bed mattress

	Accelerometer Sensor	Reporting object movements	On the doors of the fridge, pantry and front door
	Contact Sensor	Record open/close status of door	Front door

3.2 Activities of Daily Living

The novelty of the SSH platform is its objective and personalised measure of ADL components and scoring through non-wearable and non-intrusive sensors in the home environment; as well as the ability to correlate this measure with self- or carer-reported status of health and wellbeing. Clinical assessment of ADL performance, in practice, may or may not be based on objective assessment of ADLs (at discrete time points) and often relies--at least to some extent--on subjective reports from the client or carer. Measuring functional independence from environmental sensors allows for objective assessment of an individual's activities of daily living and for regular assessments over time (as opposed to discrete time points). The SSH system can learn the individual's activity profile and compare ongoing measures of their functional status with their individualised baseline level of function. This allows timely identification of changes in function and earlier intervention by ACSPs.

The domains--meal preparation, dressing, hygiene, mobility, transfer, and socialising--and the ADL score, are derived through aggregation and artificial intelligence (AI) analytics from the range of sensors deployed in the home, as mentioned above. Data from the sensors is collected over a 24-hour period (the data is not "real-time"). The data from the range of sensors are analysed to predict a client's functional performance across the functional domains (that is, meal preparation, dressing, hygiene, mobility, transfer, and socialising).

These data are then compared with the clients' own baseline activity profile data (based on data collected over a 21-day baseline period). Deviations from the baseline activity profile in each functional domain activity are shown in a graphical interface (using a traffic light system of colour coding and emoji icons) to convey whether the data was expected (green), unexpected (orange) or very unexpected (red) for that individual client. The definition of "normal" is any value that falls within one standard deviation of the mean, the "unexpected" category is any value that falls between one and two standard deviations. The "very unexpected" is for any value that falls outside two standard deviations.

3.3 SSH Applications

Client Mobile App

Clients access the progress and summary information derived from the SSH platform, via a tablet with a SSH app. The app interface was designed with research participants during earlier SSH studies. The app displays the progress status of the client's daily activities of living.

An example of the app's dashboard reflecting the daily status of health and wellbeing is represented by the different coloured rays (Figure 2). A three-quarter extension of the ray indicates an individual achieving their expected goal of health or wellbeing measures, whereas a ray below is a decline and full ray is an increase in their state of wellbeing.

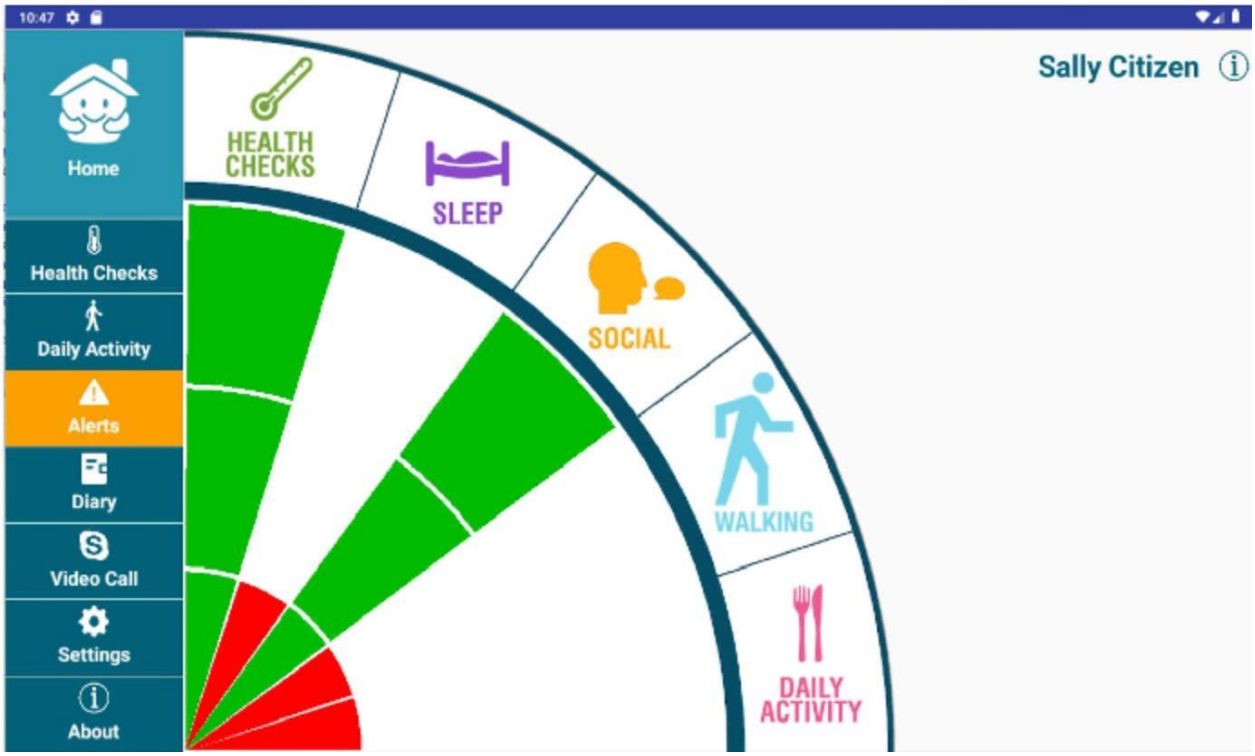

Figure 2. SSH tablet application allows clients to view data derived from sensors.

Family Portal

Family members (and/or friends) of older adults living alone are often anxious about the older adult's welfare. The SSH platform includes a portal that allows family members or nominated contacts insight into the lives of their older family member by communicating some information pertaining to the person's everyday life via a web app (Figure 3). There are four levels of access that the client/older adult can make available to family members or nominated contacts. The family portal information is presented in the same format as the client app.

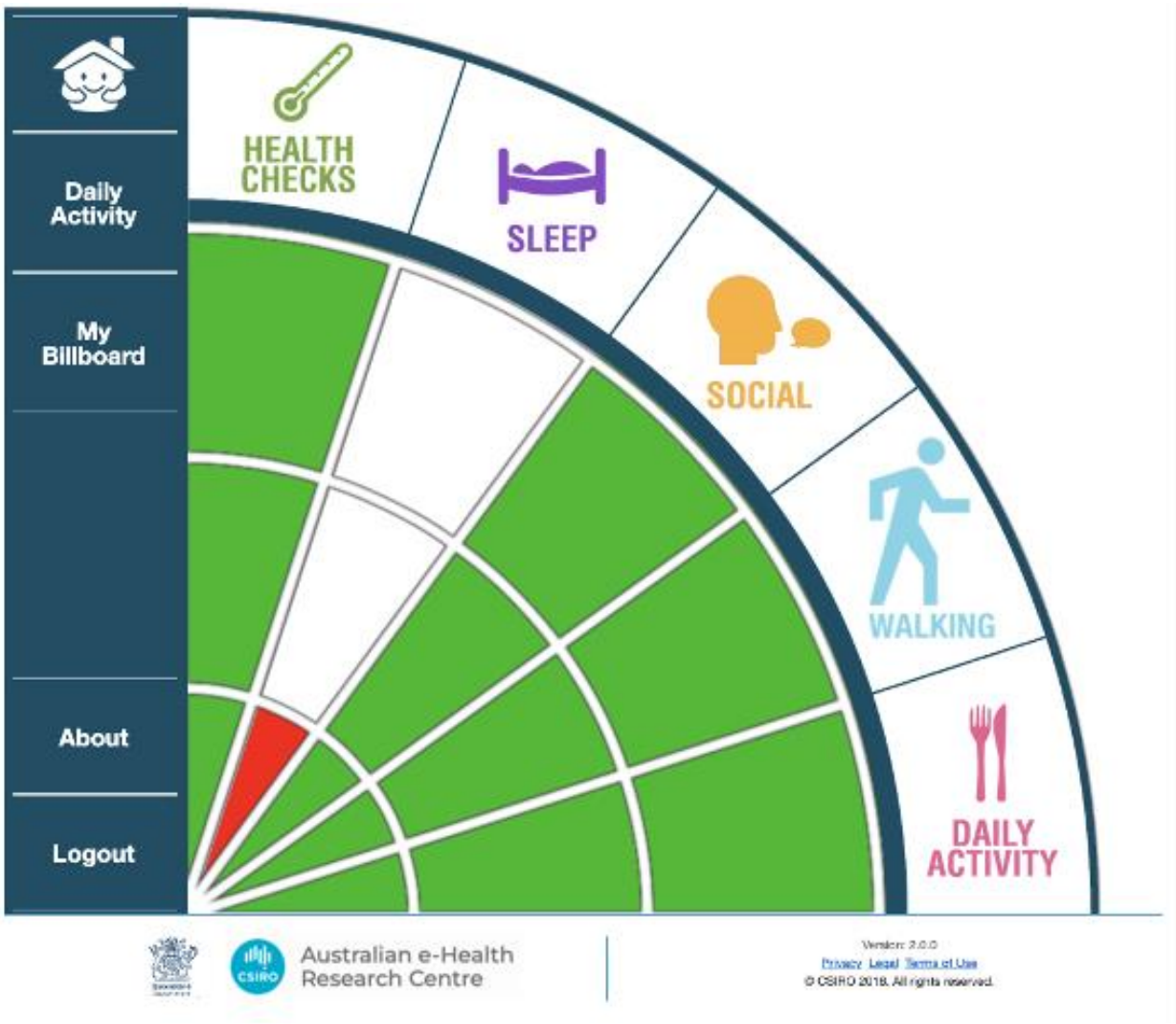

Figure 3. Family portal available through internet browser allows approved family members to view client data.

Service Provider Portal

The service provider portal (Figure 4), as part of the SSH platform provides access for professionals, such as ACSPs, to monitor a client's profile. The dashboard shows the service provider if the client's routine differed from what was expected, compared to the client's own usual routine collected during a baseline period. The monitoring system offers the potential for those who have access to the system to "check-in" regularly to see how the client is managing with day-to-day tasks. The portal also has the capacity to present a client's ADLs over various time periods (for example, weekly or monthly).

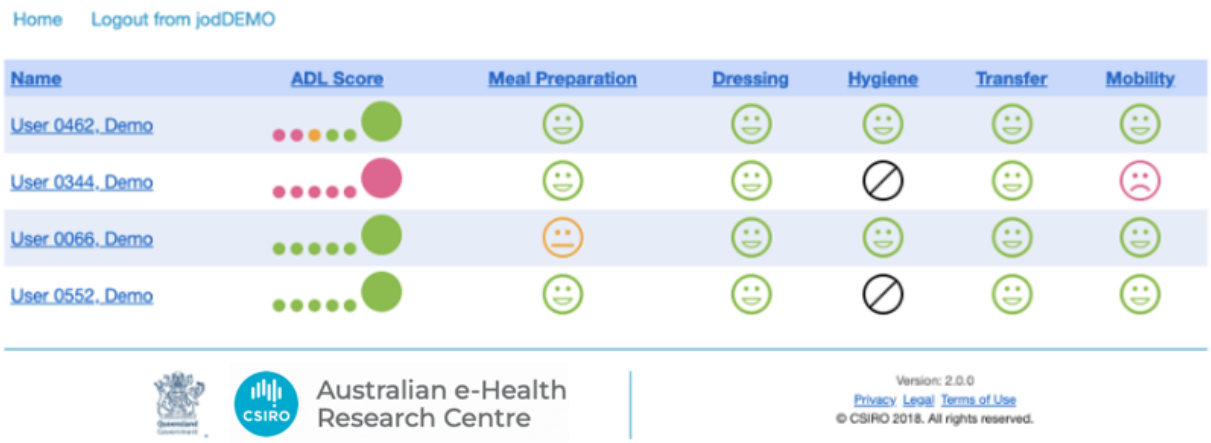

Figure 4. Service provider portal includes a list of smart home clients

4 The DACS Research Trial

4.1 DACS Trial Description

The DACS trial commenced in April 2019 and was completed in November 2020 and a subsequent paper published outlining the research protocol methodology (Zhang et al., 2022). Recruitment took six months, and each research participant was monitored for 12 months maximum. The trial was a randomised controlled trial (RCT) focussed on two geographical areas, one metropolitan and one regional. The setting was home-based, with participants living in their own residence in the community, either alone or with one other person. All trial participants received their usual aged care services throughout the trial, regardless of whether they were randomised to the control or intervention groups. The participants varied greatly in terms of the level of support and types of services that they were receiving but all received either CHSP or HCP funding.

The trial was delivered in partnership with three ACSPs: Anglicare Southern Queensland (AngSQ), integratedLiving Australia (iLA) and All About Living (AAL).

The trial aimed to recruit 200 individuals aged 65 years and older. Table 4 provides a breakdown of the number of individuals planned to be recruited from each service provider in the two geographical areas.

Table 4. Number of participants planned to be recruited.

	Anglicare	**integratedLiving**	**All About Living**
Metropolitan Area	100	25	20
Regional Area	40	15	0

4.2 DACS Recruitment

The trial recruitment was conducted between April 2019 and November 2019. From the three ACSPs 1,086 current clients were identified as eligible for the trial and offered an opportunity to participate in the research. Of those, 195 consented to participate in the trial. 140 participants were from metropolitan areas and 55 from regional areas in Southeast Queensland. All participants received either a Commonwealth Home Support Programme (CHSP) or a Home Care Package (HCP). Research participants were randomly allocated into two groups: the Usual Care (control) group and the Smart Home (intervention) group. The Usual Care group continued to receive their existing care from the ACSP whilst the Smart Home group, in addition to receiving their usual services, had the SSH kit (including sensors, android tablet and sensor hub) installed in their home.

The inclusion criteria used for recruiting participants for this trial were:

- Aged 65 years and older.
- Living at home in the care of a designated ACSP.
- English speaking, proficiency in written English.

The exclusion criteria included:

- People residing in long term residential care.
- People who are unable to give informed consent due to reasons such as severe cognitive impairment.
- People who were unwilling to leave their electricity on overnight.
- People residing with more than 1 person.

Table 5 shows participants' demographic characteristics at the commencement of the trial.

Table 5. Demographic factors by study groups at baseline.

	USUAL CARE		SMART HOME	
	N	Baseline	N	Baseline
Demographics:		Mean± SD or n (%)		Mean± SD or n (%)
Age (years)	97	81.5±7.8	98	82.7±7.1
Gender	97		98	
Male		27 (27.8%)		33 (33.7%)
Female		70 (72.2%)		65 (66.3%)
Living area	97		98	
Metro		70 (72.2%)		70 (71.4%)
Regional		27 (27.8%)		28 (28.6%)
Home care package	97		98	
CHSP		39 (40.2%)		39 (39.8%)
HCP Level 1		3 (3.1%)		5 (5.1%)
HCP Level 2		24 (24.7%)		30 (30.6%)
HCP Level 3		16 (16.5%)		14 (14.3%)
HCP Level 4		15 (15.5%)		10 (10.2%)
Marital status	97		98	
Never married		5 (5.2%)		4 (4.1%)
Married/De-facto		32 (33%)		37 (37.8%)
Widowed		45 (46.4%)		43 (43.9%)
Divorced		11 (11.3%)		10 (10.2%)
Separated		3 (3.1%)		4 (4.1%)
N/A		1 (1%)		0 (0%)
Living arrangements	96		98	

Living alone	61 (63.5%)	51 (52%)
With partner	31 (32.3%)	35 (35.7%)
With son/daughter	1 (1%)	8 (8.2%)
With related individual	1 (1%)	3 (3.1%)
With non-related individual	2 (2.1%)	1 (1%)

4.3 DACS Project Objectives

Aim

The aim of this study was to validate the SSH technology to support older community members living independently at home. The trial investigated the impact of implementing smart home technology on self-management of, and ACSPs care delivery to, older persons living independently in their own homes.

To address the aim of the trial, a research framework was developed including the following research outcomes:

Primary outcome measure:

- Social care-related quality of life (Australian Community Outcomes Measurement (ACCOM), adopted from Adult Social Care Outcomes Toolkit (ASCOT) for Australian population).

Secondary outcome measures:

- Health-related quality of life (EQ5D 5-L survey).
- Functional independence (Katz Index of Independence in Activities of Daily Living, Katz ADL).
- Depression (Geriatric Depression Scale).
- Health service utilisation (PBS, MBS data, Queensland Health Linkage Data and ED data sources).
- Changes in service design, adoption and aged care service provider experiences (focus groups).
- Care giver burden (Zarit ZBI-12).
- Costs to the government of the deployment of the SSH platform.

4.4 DACS Results

The results demonstrated a positive outcome against the primary outcome with no observed benefits against the secondary outcomes. Details against each measure are outlined below in Table 6.

Table 6. Summary of trial results.

Primary Outcome

ASCOT (ACCOM)	For participants with HCP packages, SSH greatly benefits their social care related quality of life (10 times less ASCOT score yearly drop), thus helps them stay independently in their own home for longer.

Second Outcome

EQ5D/Katz	SSH only provides marginal benefits in maintaining older adults' Health-related quality of life (EQ5D) and functional independence (ADL).
Health economics report (PBS, MBS, Qld Health Data)	The Smart Home group did not show value for money against the Usual Care group based on costs associated with the trial. Economies of scale and commercial costs should greatly reduce the cost of supporting the technology. Based on other trials we expect that a longer trial without COVID-19 impacts may demonstrate reduced health costs (Celler et al., 2017).
Geriatric Depression Scale	There were no significant differences of change across either group.
Zarit ZBI-12	There were no significant differences of change across carer burden of either group.

Statistical analysis was conducted with the CSIRO evaluation team to further evaluate the results. The following is the summary of this work.

Statistical Methods

The survey data were analysed using linear mixed models with random effects to understand how the outcome measures were impacted by explanatory variables including group allocation (intervention/control), survey time (baseline/mid-trial/end-trial), and care funding levels (CHSP/HCP). Multiway random-effect ANOVA was used to evaluate simultaneously the effects of explanatory variables on primary outcomes.

Statistical Results

Primary Outcome – ASCOT (ACCOM)

This analysis was based on the measurement of change in a single score, the Social Care Related Quality of Life (SCRQOL) constructed from the eight ASCOT measures of quality of life that make up the ACCOM. The score reports the difference between the baseline measure completed by participants, shortly after their entry into the trial, and their final score established on the final follow-up. The changes of ASCOT scores at middle and end of trial were used as outcome variables. The group allocation, time of survey and package level were considered as fixed effects and the individual participants as random effects.

There was a statistically significant interaction between time and package level on changes of ASCOT scores ($F(2, 330.49)=3.2$, $p < 0.05$). Further analyses list the adjusted marginal mean

changes of ASCOT score for each group, and their significance of differences quantified by Cohen's d effect sizes in Table 7. The effect size is defined as small (0.2), medium (0.5), and large (0.8 or greater).

Table 7. Adjusted marginal mean of changes of ASCOT scores.

		Mid-trial	**End-trial**
CHSP Service	*Control*	-0.012(0.019)	-0.004(0.022)
	Intervention	-0.025(0.019)	-0.004(0.02)
	Effect size (d)	0.6 (Medium)	0
HCP Package	*Control*	0(0.018)	-0.04(0.018)
	Intervention	0.039(0.017)	-0.004(0.017)
	Effect size (d)	2.29 (Large)	2.11 (Large)

For participants receiving a CHSP level, the changes of ASCOT scores of control and intervention groups are all negligible, indicating participants in both groups maintained stable ASCOT scores during the 12-month trial period.

For participants with a HCP package, large effect sizes indicate that fluctuation of ASCOT scores in the Intervention group is much less than that of the Control group. Specifically, after 12 months of trial, the drop of ASCOT score in the Intervention group (0.004) is 10 times less than that of the Control group (0.04).

The ASCOT analysis indicated that:

- For participants with HCP packages, SSH greatly benefits their social care related quality of life (10 times less ASCOT score yearly drop), thus helps them stay independently in their own home for longer.

Secondary Outcome - Health-Related Quality of Life – EQ5D-L survey and Functional Independence – Katz Index of Independence in Activities of Daily Living

The changes of EQ5D/ADL scores at middle and end of trials were used as outcome variables. The Group allocation, time of survey and package level were considered as fixed effects, and the individual participants as random effects.

There was no significant interaction between explanatory variables and the EQ5D/ADL outcome measures. There were also no significant main effects of group allocation.

The adjusted marginal mean EQ5D score at the end of the 12-month trial was 0.687(0.04) for the Control group and 0.7(0.04) for the Intervention group. The adjusted marginal mean ADL score at the end of the 12-month trial was 5.40(0.2) for the Control group and 5.43(0.2) for the Intervention group.

The EQ5D/ADL analysis indicated that:

- SSH provides marginal benefits in maintaining older adults' health-related quality of life (EQ5D) and functional independence (ADL).

Health Economics Report

A cost-benefit analysis of the DACS trial was conducted by the Health Economists at the Menzies Health Institute of Queensland, School of Medicine and Dentistry, Griffith University. A cost-utility analysis was conducted comparing the Smart Home group to the Usual Care group. The primary outcome was the incremental cost-utility ratio (ICUR) and the net monetary benefit (NMB). The time horizon was 12 months with effectiveness measured as quality-adjusted life years (QALYs) and costs including hospital, community healthcare, residential aged care, and intervention costs.

The health economics analysis indicated that the Smart Home group did not show value for money against the Usual Care group. However, there were some limitations to this analysis. These included:

- The impact of Covid-19 on MBS and PBS data that was used in the analysis could not be measured. Meaning, hospitalisations, and visits to general practitioners reduced across the population, likely due to mandates to stay at home and away from essential services. This is not reflective of medical access, as predicted at the commencement of the DACS trial.
- The health economics analysis was based upon the trial operation. Consideration should be given to outlining current market costs of installations and current sensors used. Research costs are likely to be much higher than market costs.

Geriatric Depression Scale

Analysis of Geriatric Depression Scale results showed no significant differences of change across either the Usual Care group or the Smart Home group.

Care Giver Burden Scale

Analysis of the ZBI results, from these surveys, showed no significant differences of change across either group. There were 49 Carer Burden surveys completed in the Smart Home group and 45 surveys completed in the Usual Care group.

Qualitative Analysis of Trigger Spreadsheets

Throughout the trial the ACSP partners created their own log (spreadsheet) to record information about how they used the SSH system to monitor the participants in the Smart Home group. The logs were not part of the original study design and were not standardised, although they recorded similar items. Each of the ACSPs completed these logs in a different way. The ACSPs also maintained their client's usual care notes in all instances, and these were separate to the log (so the logs did not form a complete record of the actions taken for the participants and CSIRO were not privy to confidential care notes).

The type of information recorded in the spreadsheets included:

- when the system was checked
- what triggers were seen
- how the providers responded to these triggers.

To help the researchers understand how the service providers were using the SSH system, all available trigger spreadsheets were analysed (n=73). While collating this data provides the research team with some insight into how the ACSPs used the system, the service provider logs was not originally intended to be used as a trial outcome or for any type of analysis. The data includes participants who withdrew from the study (up to the date of withdrawal).

System Triggers

The ACSPs aimed to check the SSH Service Provider Portal (Figure 4) five out of every seven days, that is, on business days. They reviewed individual trends for meal preparation, dressing, hygiene, transfers, or mobility to see if these differed from the baseline level of function. Each time the ACSPs checked the system they noted whether one or more of the functional domains was in the unexpected or very unexpected range for that participant. The participants' sleep data was also collected however this data did not show up on the front page of the Service Provider portal and did not appear to be included in any of the provider monitoring logs (so it was unclear whether this information was being monitored or viewed by the ACSPs).

In total, across the 73 participants included in the collated ACSP spreadsheets, the system was checked by ACSPs, a total of 11,116 times in 12 months (Table 8). Of the days that the system was checked, there were 6,217 (56%) occasions where a "trigger" in one (or more) of the functional domains (orange, or red faces with a black circle strike through indicating no data collected at all) indicated that this differed from the baseline data. On 4,899 (44%) occasions the system did not show any triggers (all domains showed a green smiley face).

Table 8. Number of system checks by ACSPs.

n=73 participants	Total Number of Instances	Percentage of the number of days the system was checked
Total Number of Days the System was Checked	11, 116	NA
Number of Days the System Triggered	6217	56%
Number of Days the System Did Not Trigger	4899	44%

Single/Multi-domain Triggers

The system triggered on 6,217 days across all the participants, however in total there were 11,021 individual triggers. On 3,245 days the system was triggered across multiple domains (combination trigger) (Table 9).

Table 9. Number of system triggers.

n=73 participants	Total Number of instances	Percentage of the number of days the system was triggered
Number of Days the System Triggered	6217	
Number of Days with a Single Domain Trigger	2972	48%
Number of Days with Triggers across multiple domains	3245	52%

Functional Domains that Caused Triggers

The 5 domains that were checked are listed below (Table 10) with the total number of times that this particular functional domain was the trigger. Transfers (31%) and mobility (30%) were the most common system triggers.

Table 10. Triggers per domain.

n=73 participants	Total Number of Instances	Percentage of the total number of individual triggers
Transfer	3423	31%
Mobility	3275	30%
Meal Prep	1548	14%
Hygiene	1410	13%
Dressing	1365	12%

Technical vs. Non-technical Triggers

When the system triggered, the ACSPs would first check if the trigger was due to a technical issue. In 3,334 (47%) instances the ACSPs identified that this was the case (Table 11). In 3,689 (53%) instances there was a non-technical issue causing the trigger (Table 11). This adds up to more than the total number of days triggered as there were 746 instances when there was a combination of both technical and non-technical issues causing the trigger. For example, if there was a technical issue with the chair sensor which causing the transfer sensor to trigger, but the system was also triggering for mobilty, irrespective of technical issues, this was recorded as a combination of both technical and non-technical issues).

Table 11. Numbers of technical V non-technical triggers.

n=73 participants	Total Number of Instances	Percentage
Non-Technical Issues	3689	53%
Technical Issues	3334	47%
Combination of Technical and Non Technical Issues	746	

Decision Making About Contact as a Result of a Trigger

When the ACSPs identified a trigger they then needed to act. An agreed protocol outlined that the ACSPs would typically wait until there had been 2 or more days of non-technical “triggers” before contacting the participant. The providers recorded in the spreadsheets their decision making about what to do when there was a trigger. Table 12 provides a summary of the recorded decisions of ACSPs, grouped by theme.

Table 12. Recorded decisions of ACSPs, grouped by theme.

n=73 participants	Total Number of Instances	Percentage
Known Technical Issues	2583	42%
Wait	2253	36%
Contact Already Made	1092	18%
Email Sent to Case Manger	140	2%
Contact	144	2%

On 2,583 (42%) occasions a decision was made not to contact the client as the trigger was due to a known technical issue. On 2,253 (36%) occasions, the trigger was not a technical issue, but the decision was made to wait before contacting the client. On 1,092 (18%) occasions the decision was made not to contact as contact had already been made recently. In 4% of cases the decision was

made to contact the client and either contact was made directly with the participant (2%) or an email was sent to the client's case manager requesting that they make contact with the participant (2%).

Contact with the Participant

In some cases, it was unclear whether a decision to contact the participant actually resulted in contact with the participant e.g., if an email was sent to a case manager the case manager's contact with the participant was not always recorded in the log so it was unclear whether or not contact was made. However, from what was recorded in the logs a trigger resulted in contact with the participant in 223 cases (3.55%) (Table 13).

Table 13. Numbers of contact V no contact.

N= 73 participants	Total Number of Instances	Percentage
Trigger Resulted in Participant Contact	223	3.55%
Trigger Did Not Result in Participant Contact	6056	96.45%

Trigger Causes

Where the trigger was not technical the ACSP usually recorded a reason or a suspected reason for the trigger. This cause was usually determined by contacting the participant or family member or by cross-checking with other records (e.g., hospital records or other care/clinical records). In some cases, the cause of the trigger was also documented against subsequent triggers that the providers felt were also because of this cause. In total there were 1469 days where a non-technical suspected cause for the trigger was recorded. In 579 (39%) instances the reason recorded for the trigger was a health issue (e.g., short term functional decline, progressive functional decline, client unwell, fall, and so forth). In 421 (29%) instances the reason recorded for the trigger was a routine change (e.g., seasonal routine change, COVID-related routine change, increased time away from home, changes for household member). In 277 (19%) instances the reason recorded for the trigger was that the client was away from home. In 192 (13%) instances the reason recorded trigger was unclear (Table 14).

Table 14. Numbers of triggers per category.

Category	Subcatagory	Total Number	Percentage
Total Number of Triggers Causes Recorded		1469	
Health		579	39%
	Progressive Functional Decline	422	29%
	Short Term Functional Decline	77	5.24%
	Client Unwell	77	5.24%
	Fall	3	0.2%
Routine Change		421	29%
	Non-functional Routine Change (eg. Seasonal)	216	15%
	COVID related routine change	119	8%
	Changes for household member	70	4.4%
	Household Member Away	48	
	Household Member Moved	16	

	Household Member Functional Decline	6		
	Increased Time Away from Home	16	1%	
Client Away From Home		277		19%
	Client Away	167	11%	
	Client Hospitalised	110	10%	
Unclear		192		13%
	No documentation	67	4%	
	Unclear Cause (?False Alarm)	125	9%	

Action Taken

When contact was made with the participant this resulted in further action being taken or proposed by the ACSP in 43 documented instances (Table 15). It is unclear if other action was taken but not documented in these logs and perhaps documented in the care notes of the client.

Table 15. Reason and numbers of actions taken.

Category	Subcatagory	Total Number	Percentage
No Action Taken		712	86%
Rebaselining Requested		66	8%
Services Increased		20	2.68%
	Increased Care Services	12	1.46%
	Allied Health Input	8	0.97%
Increased Services Suggested (But Not Increased)		21	2.53%
	Awaiting Higher Level of Home Care Package	15	1.8%
	Client declined services	6	0.73%
GP contacted		2	0.24%

Summary of Service Provider Logs

The data collected shows that:

- The system was checked 11,116 times by service providers.
- There were 223 instances where contact was made with the participant.
- There were 43 instances when intervention was suggested (additional supports or general practitioner (GP) review).
- There were 20 instances when additional supports were put in place.

Actions were taken by the ACSP only for a small percentage of the time when looked at as a proportion of the total system checks (0.17%). This number may seem more significant when compared to the number of participants (e.g., 73 participants monitored across the course of a year resulted in 43 proposed actions and 20 actions being taken).

The data from the logs are helpful in showing that the current SSH is particularly useful at identifying:

- progresssive functional decline
- changes to a participants routine, and
- periods where the client is away from the home.

However the system was not designed to detect real-time monitoring and is therefore less useful at detecting acute events such as falls and emergency situations.

Impact of COVID-19

It should be noted that the Covid-19 pandemic impacted the DACS research trial. The impact of this meant that no visits to homes could occur from the middle of March 2020 until the end of May 2020. Most aspects of life that were being measured in the trial were impacted by restrictions on visits to homes, hospital and medical appointments for the participants, and a trend of participants cancelling non-essential services. At the time of the first lockdowns in March 2020, ACSP partners also reported that socially based services were being restricted e.g., outings to respite centres and recreational visits. These changes did not impact the trial for all enrolled as some participants were coming to the end of their trial participation at the time of the first lockdown (that is, enrolled in April 2019, then completed the trial in April 2020). However, the inability to visit homes did mean that CSIRO project officers could not provide service maintenance of sensors (e.g., battery changes) and there were periods of time where data was not reliable as a result. Risk mitigation steps were taken, and participants were made aware of this.

While this impact is accounted for in some ways in the analysis of the DACS trial results, there are still questions over what the true impact was and whether or not the researchers account for this impact in any of the planned measurements. This should be considered when reading the results of the DACS trial.

4.5 How Smarter Safer Homes Intervention Differs from Usual Care

Usual Care

The service providers explained that prior to the implementation of SSH the trial participants were receiving aged care services either through CHSP or through an HCP. The clients receiving CHSP services were only receiving low intensity services (e.g., fortnightly cleaning) and were not reviewed regularly for clinical or functional needs, unless the client approached the service provider directly about a change. The clients receiving services through an HCP would have intermittent reviews by a case manager but the services the client received were based on client report/preferences.

Prior to the implementation of SSH the ACSP was not providing daily monitoring of the participant's function/care needs and even those participants who had carers coming into the home regularly did not necessarily receive regular monitoring of changes in their functional abilities or care needs (as this was not the primary role of the carers coming into the home).

> "*If you are providing care, you are more focused on the action*/service *only (e.g., cleaning or showering) …. rather than how the client is managing other functions."*

> "*CHSP clients are not reviewed regularly for clinical needs or activities of daily living, unless they approach us.*"

"*24/7 monitoring is not available.*"

Intervention Group

In the Smart Home group, the participants received additional services (on top of their usual care). Exactly how the SSH system was used and implemented differed between providers. Mostly a single staff member was monitoring the portal 5 days/week. This person monitored the portal, checked whether there were any deviations from the participant's baseline level of function, interpreted what they were seeing, and determined whether a call to the participant was needed.

The staff member monitoring the portal varied between providers in several ways:

- Experience and qualifications of the staff member
- Whether or not the staff member had direct contact with the participants
- Whether or not the staff member was involved in providing services to the participant.

The ACSPs indicated that most of the time when they contacted the participants there was an explanation for the change in routine, although it was not always related to the participant's health/functional needs.

> "*Movement or hygiene could be changing depending on the weather or the season.*"
>
> *"Usually, logical explanations for it …. So that didn't result in a change to the care plan."*
>
> *"Actually, it did reflect a change to their activities of daily living, but it wasn't requiring increased services.*"

5 Impact findings of Smarter Safer Homes

5.1 Impact on Participants

In the DACs trial, participants were asked for their feedback, comments, and suggestions as part of their final survey (End-Trial Survey). ACSPs from the DACS trial were also asked to give information during a post-trial interview which included questions about any feedback that clients had given to them, during the trial.

Non-Intrusive

Most of the participants reported that the sensors were not intrusive:

> *"Didn't even know it was there"*
>
> *"Pretty harmless"*
>
> *"Was not interfering at all"*
>
> *"After such a long time I have totally forgotten that the sensors are there"*
>
> *"Don't worry him at all"*
>
> *"After a few weeks I totally forgot the sensor was there"*
>
> *"I didn't feel it had been intrusive"*
>
> *"Most participants said that once it was all set up, they just carried on life as usual and forgot it was there"*
>
> *"Most of the time I wasn't even aware it was there; it doesn't intrude in any way"*
>
> *"I just got so used to them in the end that they were there and totally forgot about them a lot of the time*."

Participants' Feeling of Safety/Security

The participants themselves described a sense reassurance from having the system in place and feelings of safety and security. The ACSPs indicated that their impression of the system was that participants felt a sense of safety and security from having the system in their home.

> *"I knew if something happened to me, you guys would be there as a – to say, well are you okay?"* – Participant.
>
> *"it's just sort of making sure that you're okay"* – Participant.
>
> *"The sensors do go off but that is like a little LED goes off. That says to me I've got a friend looking after me."* – Participant.
>
> *"The system puts some sort of alert up so that someone will ring or come and find out if you're all right. I think that's a great thing"* – Participant.

"Just the knowledge that if these people monitoring it didn't get any – pick up any movement that there would be a – they would get in touch and find out if everything was okay with me" – Participant.

"I think people like me who live alone, so they're getting older, I think we need some sort of surveillance system that, as I say, doesn't need a response from us and that if we're disabled or something will alert the computer somewhere that will set a thing in motion, someone will come and have a look at us, but you can't have everyone walk in the door every day to see if you're okay." – Participant.

"Well as far as I was concerned, it was great. I appreciated the fact that someone had – if I didn't move out of bed, if I didn't do something for the day, I would get a phone call to say, are you okay, there is nothing wrong." – Participant.

"I would much rather have this in my home because I forget it's there most of the time. Much rather have that and know that somebody know the time that something's gone wrong, then have to move into residential care, because otherwise I'm not safe." – Participant.

"It's almost having that other - the third eye looking in there, the big brother looking in there for him." – Family Member.

"Participants themselves felt an extra layer of security, having the technology and having and the knowledge that you know if something was to go wrong, or if they declined rapidly, that there was another pair of eyes on them" – Service Provider.

"So some of them felt quite secure knowing that someone is sort of keeping an eye on their life...if something happens to them, someone's watching them that." – Service Provider.

"A sense of improving confidence and security." – Service Provider.

"We had a lot of comments how the technology made them feel safe. So, really key words that people were saying." – Service Provider.

Benefits

Several participants made comments about feeling that the system was beneficial to them, and some commented that it could be beneficial to other people.

> *"I loved it. It was a good feeling when someone called and asked if everything is OK. It made me feel better."*
>
> *"Was wonderful to be a part of."*
>
> *"Thinks having the sensors installed would have been very helpful for me."*
>
> *"Hopes it will be useful for people who are living on their own."*
>
> *"She thinks it would be a wonderful help for families and relatives".*
>
> *"Well as far as I was concerned, it was great. I appreciated the fact that someone had – if I didn't move out of bed, if I didn't do something for the day, I would get a phone call to say, are you okay, there is nothing wrong?"*

"I think that's the best thing that ever came out of that, but for people that want to continue living in their own homes, that will be a big plus, that there will be someone monitoring."

"There's a lot of older people that don't have anyone to check on them and they're sick and sometimes we get a bit independent, and we won't ring anybody."

"I'd recommend it (the SSH) *to them, that would be alright. I mean if it's going to help people, why not, eventually in the long run."*

Some liked having the system in place

"I think when you come to take things out, I will miss the one in the bedroom. She gets out of bed occasionally and thinks it is all working" - Participant

"Says goodnight to them of a night-time" - Participant
"It was a good experience, yeah, and I felt good doing it" -Participant

"A participant mentioned that they loved the technology and how devasted they were that the technology had to be withdrawn from their homes at the end of the trial" - Service Provider.

Sensor lights

Many participants mentioned noticing the lights on the sensors.

"Sometimes noticed the lights flashing (but got used to it over time)."

"The sensors were alright; they lighten up my place."

"A participant used it for lighting when she was getting up to go to the toilet at night."

"Some participants told me they could see the lights."

"When I moved around of a night-time, they come on, so there was always a little light around."

"It was great at night because I'd get out of bed to go to the loo and I'd walk into the bathroom and I could see where I was going. I liked the little green flash."

"When I moved around of a night-time, they come on, so there was always a little light around."

"The light in the fridge was a bit of a treat. It goes flashing all the time."

"The light in the wardrobe, I looked for it whenever I moved my clothes in the wardrobe."

"At first it gave me a little bit of a fright when I opened up the wardrobe at night-time, but then I got used to it."

Sense of being watched

Some participants indicated initial concerns about a sense of being watched but were reassured once they received additional information.

> *"My carer felt like big brother was watching me."*
>
> *"The thing works, as I saw, it's just picking up movement or heat or whatever, it's not watching what you do, and it doesn't know what you're doing."*
>
> *"It's not photographing you, so there's no image there."*
>
> *"I was reassured that it would not be invading my privacy, so - I'm not a worrying type."*
> *"I had a few people that sort of looked at them very suspiciously and asked if they were cameras."*

Limited client engagement with data

Participants and ACSPs both indicated that the participant engagement with the client portal was mostly quite limited. Although a few participants engaged with the portal, some participants reported difficulty understanding it or not feeling sure what to do with the client portal.

> *"I did look at it but I didn't really look at it much. I just tried to look at it a few times and didn't quite get it, so I just left it there. I didn't really look at it, no."* – Participant
>
> *"I don't need to check up on you or the program. You're doing it for a good purpose, so I don't need to be keeping an eye on you all the time."* – Participant
>
> *"I'm not a computer or data person"* – Participant
>
> *"I didn't access it because I wasn't sure how to use it."* – Participant
>
> *"I didn't really know how to use it so they did sort of basically show me what was going on but then I didn't seem to see much, so I just left it alone"* – Participant.
>
> *"Yeah, had a look and see what it was doing and noticed the days when I'm...I'm out all-day it was big red marks on that day…Then on the Sunday when I had the visitors it was through the roof. Yeah. So, it was interesting to see how I was moving around and where I was and all that type of stuff" -- Participant*
>
> *"I think I only went to it once or twice. Life is very busy, and I have my own iPad and iPhone and computer and that keeps me busy enough with all - up to date with all those things that I want to keep up to date with."* – Participant
>
> "*I know one of the participants was pretty keen with monitoring their own movements ……. most participants didn't bother to read and interpret the data on their own, so it's just staying in one of the drawers or something."* – Service Provider
>
> *"Internet's a barrier sometimes"* – Service Provider
>
> "*Education for the participants (DVD or something like that) the system and easy fixes if technical issues*" – Service Provider.

Concerns about lack of emergency response

Some participants raised concerns that the timeframe for response (which could be up to 48 hours) was too long.

> *"I had a fall before last Christmas, and this doesn't register. I think it would be good if this registered. Was on the floor for about 10 minutes. I didn't have my falls monitor on at night."* – Participant.
>
> *"Not so much for me but for people it should be -- not necessarily installed either but available if people are wanting to live alone - is for safety, to keep people's state of mind to know that they're going to be safe, not have to lie on the floor for 24 or 48 hours."*
>
> – Participant.

Other participant feedback

Participants had some suggestions about improvements to the system.

> *"Keep the technology simple."* – Participant.
>
> *"I was a bit worried about whether they'd come off the wall without taking the paint off, because I'm still renting at the moment but there was no problem at all with them."*
>
> – Participant.
>
> *"I picked it up about four times and stuck it back on in the bathroom or whatever and then it just kept falling off, so I just left it on the floor.*" – Participant to Service Provider.
>
> *"Yeah, it was a good talking point. The little ones come here and then they'd see that light going on and you'd explain to them why and everything like that and [it was] good."*
>
> – Participant.
>
> *"I can't really see the major benefit of this system as it is, just looking for a level of deterioration."* – Participant.
>
> *"I do think that it should be mandatory for elderly people to be on that light on the jug and on that microwave. That was good technology that."* -- Participant.

5.2 Impact on Aged Care Service Providers

Three (n=3) in-depth interviews were conducted with ACSPs following the DACS trial. These interviews covered:

- how the SSH intervention differed from usual care
- the ACSPs perceptions of the impacts of smarter safer homes
- barriers to implementation, and
- possible future directions.

5.2.1 Service Provider Perceived Impacts of SSH

Additional Insight/Information

The ACSPs reported that SSH had a considerable positive impact on care facilitation and identifying care needs of the participants. Providers described the SSH technology as being a "third eye" or a "fisheye lens" providing greater insight and a broader understanding into the participants needs and leading to opportunities to provide more targeted care. This information would not have been available in traditional care delivery model.

> *"More regular monitoring of the client."*
>
> *"Another level of knowledge about what was going on in the participant's home."*
>
> *"Sometimes … the case manager would ring the client…how's everything going? …The client would say that everything was fine. This technology has enabled us to actually see things that the client may not be telling us."*
>
> *"Visibility of the potential additional supports that clients need."*
>
> *"I think that it's been able to give us such a deeper level of understanding what goes on inside older Australians' homes."*
>
> *"Without SSH, especially for the regional area, probably it would have been difficult to keep in close contact with them, and even the clients who they visit and provide services to they aren't with them 24/7 so the monitoring device tells you an average of the day…whether they have been keeping up with their normal regular days."*
>
> "G*et to see the inside of the persons actual lifestyle, that would have been difficult when they didn't have that technology.*"
>
> "*Those more personal things that people might not volunteer information e.g., around toileting and hygiene so are particularly important.*"
>
> *"It opened the door for us to approach them if we could see something that was changing, especially a reduction in certain things like moving around a lot less.*"
>
> *"I can say for sure that the sensor data was helpful in directing where the conversation needed to go. Then getting to the bottom of how they really were coping with some of the ADLs and finding out that they weren't and then requesting a reassessment with My Aged Care, which resulted in them being reclassified and accessing higher services. So, that wouldn't have happened yet. It probably would have waited till there was a crisis."*
>
> *"I think it was a good indication, because as I said it gives you the daily activities and things, so it definitely gives the insight, so you act more if you do see any unusual activities going on."*

More Targeted Care

This additional knowledge provided by the SSH system led to opportunities to improve and target the participants' care, however ACSPs noted that the trial did not allow enough time to implement some of these changes and that the limitations of the aged care system (e.g., needing to wait for

assessments/access to HCP funding) meant that services could not be increased in a flexible or timely way.

> *"Deeper understanding of additional supports that we could potentially be assisting them with."*

> "*One participant wasn't moving around as much…the technology triggered an additional care conversation…And we were able to target…the case manager was able to specifically ask that….the participant stated they didn't feel easy on their feet at the moment…So, we were able to go in and do an OT* (Occupational Therapy) *assessment and put some grab rails in or provide a wheelie walker, things like that…really quite fundamental preventative measures, that the sensors were able to notify us to have that conversation."*

> "*I noticed that somebody was up a lot during the night, so going to the toilet a lot and so we were able to talk about that, which is a conversation that these people don't necessarily volunteer that sort of information, so he was then able to have a medical review, some medications/equipment to help with that.*"

Improved Communication

Greater communication was cited as an important benefit of the technology. The ACSPs described how communication improved between all stakeholders, and that this had unexpected "trickle-down" benefits. For example, those monitoring SSH were able to alert family when they thought that the client may be needing additional support and this type of alert allowed for greater engagement and opportunities for conversations. These conversations were described as more timely and more in-depth than with usual care, as the conversations were "triggered" as opposed to left to wait until it was too late, or the timing was 'right'. One provider also described they felt that the phone calls triggered by the system to the client, impacted on "breaking up isolation" and that they felt their "call and conversation was appreciated at a deeper level than just for care delivery."

> *"This technology has allowed us to have additional conversations with our clients, and also specifically more targeted conversations."*

> *"Facilitates targeted conversations with clients."*

> *"We may notice the client isn't…they're not as mobile as they were last week….so the case manager is then able to have a really specific targeted conversation with the client that they wouldn't have previously, because of the data and information they have seen from this technology."*

> *"Example, I can see that you haven't been moving as much this week, is there anything you need additional support/help with?"*

> "*Clients aren't always that forthcoming with letting us know that they need additional support…So, this technology allows us to actually initiate conversations, and not be so reliant on them being proactive with us.*"

"It really connects the client with their case manager… because they had better understanding of their needs and better insight into what was going on in the home."

"It's also really opened up the kind of conversations that we're having with our clients…better relationship that our case managers are having with the clients."

"Some of them found it quite pleasant to talk to use every now and then, saying thank you for doing that, I guess it's more like a social monitoring as well."

"Gave us the opportunity to start a conversation that you would have otherwise been clueless about."

"We've been able to assist that participant with having a reassessment for a higher-level package. But in saying that, that wasn't directly from what we saw coming through the portal. It was more having conversations. But, I guess, we wouldn't have had those conversations if the person didn't have the technology in their home."

"Sensors alone are not good without the care conversation."

Providing Empirical Evidence for Increased Service Provision/Funding

ACSPs described the value of having empirical evidence of the participants' care needs to support the need for increased care. This was particularly helpful when advocating for increased funding or a higher priority to access funding. Access to data enabled participants and their supporters to advocate for more appropriate and timely care.

"Technology would be really useful to be able to use when advocating on behalf of the client for a higher level of funding."

"Could be used as evidence to support their application for a higher level of package, higher level of funding."

"Ability to be able to extrapolate the data and have really good solid evidence of someone's need for increased funding."

"Useful to advocate on behalf of people who may not be getting the level of support that they need. Or who have been in the national queue, waiting for a higher level of package…. this is really good evidence to prove that, that they're needing further assistance now."

Concerns about False Sense of Security

There were some concerns from ACSPs about participants expectations of the system and that the technology could provide a false sense of security. The ACSPs highlighted the importance of good communication to ensure participants understood that the system could not alert the ACSP of an emergency.

"*I think people still did expect, even though they were being monitored 1x/day, 5 days/week, that people still did get the impression that if they had a fall, we'd know and we'd help them. So that that kind of stuff is important in the communication with this.*"– Service Provider.

"*Need for good communication of who is checking the system and when (e.g., not an emergency monitor, only checked weekdays because I could see that it could give a false sense of security. Even if you have 24/7 monitoring unless you have some way of alarming in case of suspected emergency.* "– Service Provider.

Ease of Use

The ACSPs mostly found the provider portal easy to understand and interpret, however some providers indicated that more detail would have been helpful.

> *"It's very, very easy to access, interpret and see what's going on."*
>
> *"That (the timeframe) was enough to determine the patterns, to have something to talk about."*
>
> *"It could have been a little bit more detailed, because judging people's activities with three different statuses, I thought that might be a little bit too vague."*
>
> *"No fine adjustments. It's hard to tell whether it's just a little bit of a miss or a big miss. How far away from baseline would give a little bit better idea of participants."*
>
> "*No sensor in the garden so it would not pick the motion outside the house*."
>
> "*Green light or more motion is not always positive reaction – more detailed would help.*"

5.2.2 Barriers to Implementation

While the feedback from ACSPs was overwhelmingly positive regarding the technology, they described several areas for improvement and their perceived barriers regarding the sustainability of the technology.

Costs

It was acknowledged that the facilitation of the monitoring and upkeep of the hardware was quite resource heavy. However, this could be alleviated by providing greater training and/or contracting the SSH out to a third-party.

> *"Duty of care for regular monitoring. Once you've got it installed and the portal is activated on. There will have to be some sort of costing to have somebody monitoring the portal every day."*
>
> "*Not just monitoring it but making the appropriate the follow up calls. So, with you know 20 or so participants being monitored. There is sometimes if you've got a call. The colours are helpful, but I guess if you had to then call multiple people, it does take a bit of time, so there will have to be a sort of some kind of costing figured out."*
>
> *"A decision about how it would be applied to each person's care, you might expect that it's quick, but it's not, it takes time*."
>
> "*Greater benefit for the family member than service providers … it's going to be a challenge to rely on service providers to be able to offer as much monitoring as people will perceive is there.*"

"Sensors alone are not good without the care conversation."

Re-baselining

The technology itself had some limitations and providers observed that they needed to re-set the baseline for monitoring more regularly than they were able to. This was because client circumstance often changed. This could be for health reasons or just because of something as simple as the weather; colder weather requiring less showers, for example:

"Over 12 months in this age cohort, there is always going to be a natural decline …so 6 months down the track the person shows up that they have deviated significantly from baseline...is that natural decline, what is significant decline?"

"Needs to be some kind of opportunity for service providers to trigger re-baseline."

"*So, if we can redo the baseline – if their normal is no longer normal, and it has been found that that's the new normal that needs to be reflected in the monitoring system.*"

"I do think you need to consider re-baselining seasonally for some people, because their whole life changes and it's a big waste of manpower. It becomes a bit awkward, so ringing a person every couple of days to find out that it's the same conversation that you had a few days ago becomes actually embarrassing for the care provider and frustrating and annoying for the participant."

"…people will have episodes where they have significant decrease, and they will never get back to their baseline. So, there needs to be some way where those people are re-baselined."

Hardware Issues

Similarly, if the hardware failed, those monitoring were unable to make changes and had to interpret data as it was available. Additional suggestions for improvements included greater sensitivity in the technology, incorporating other variables in addition to movement and the creation of an algorithm to flag if something was an emergency.

"*Sometimes sensors falling down.*"

"*Technical Support is definitely required."*

"So, I don't know how the sensor is look like, but I'm assuming it's for example bathroom, it's the one that sticks onto the wall. So, with the moisture-raised environment and stuff it's a little bit hard for the sensor to stay there, that sort of thing." - Service Provider

"I picked it up about four times and stuck it back on in the bathroom or whatever and then it just kept falling off, so I just left it on the floor. I was like, you could have put it in a drawer or something, but he didn't want to touch it, I suppose" – Participant report to Service Provider.

Policy/Funding

The ACSP providers noted that there was the need/desire to incorporate the technology at a policy-level. Providers described how it would be useful for the technology to not only align with

current care guidelines but also deconstructed into 'chargeable' service that could be incorporated in funded packages. The providers also raised the issue that they were not always able to act on the information that they saw as they had to refer on to independent assessment agencies (RAS and ACAT) to arrange additional services. While the providers could suggest re-assessment, they did not make the final decisions about whether the client received funding for increased service provision and there were some concerns that information may have gotten "lost" in translation. This process also meant that the additional services could not necessarily be implemented quickly.

> *"Staff needs to be allocated into that* (monitoring). *I don't know whether the staff will be.*" – Service Provider.
>
> *"Change in care package would be costly for the participant and provider, time consuming and because Service Providers just can suggest re-assessment some details will be lost in translation"* – Service Provider.
>
> *"If we were still monitoring in six months' time, then I would suggest that we'd be having a lot of interventions, with additional services and there would be a natural progression of more services and then an ACAT assessment and then a Home Care Package and things like that. But because of the duration of the project, we just didn't have time to really see that."* – Service Provider.
>
> *"I think the service industry, particularly for aged care, is in a very bad way. I went through all the hoops and did all the things, and it was two years before they said okay, we're at the stage where we think we can provide a package, and eventually it turned up and so on"* – Participant.

Service Provider Education

> "*Education for service providers about the system and how to approach conversations so that people felt like they were being cared for rather than watched.*"
>
> *"Session explaining what's the purpose of this system … I joined in the middle of it … I had a rough idea, but difficult to get my head around … what those sensors mean …or what those red or green or yellow faces mean."*

General Feedback

> "*No sensor in the garden so it would not pick the motion outside the house.*"
>
> "*Green light or more motion is not always positive reaction – more detailed would help.*"
>
> "C*hoosing words that might not be offensive to participants e.g., 'hygiene' might be seen as a little bit offensive.*"
>
> *"Keeping the records little bit more relative to their clients instead of the just the figures*."
>
> *"Sensors alone are not good without the care conversation."*

5.3 Future Directions

The comments indicate that the technology was well-received. The ACSPs agreed it could have several applications across health conditions and environments. For example, it was suggested that there may be cohorts of participants who would particularly benefit from the technology to help make more informed decisions about needs. For example:

- clients with cognitive impairment (who may not have the insight required to self-report care needs)
- clients living alone (or who are alone at home for long periods e.g., while family at work).
- clients whose primary carer does not live with them
- clients living in rural/remote communities
- clients that are in transition periods (e.g., between hospital and home)
- clients receiving reablement/rehabilitation (to monitor progress).

> *"To have this technology kind of in the hands of our allied health workers…"*
>
> *"Would be fabulous for people who are in transitional care – transitioning out of hospital so that they could see the progress that they had made."*
>
> *"Would be really useful in a more restorative care framework than a preventative care framework."*
>
> "C*ognitive impairment…So those people I can see a real benefit for them, because if they're forgetting to eat…or if they're not addressing personal hygiene, that kind of thing. It can be really unsafe, and you don't know until it escalates or until they have a fall or something*."
>
> *"Where I can see a real value is if you've got, you know, like a son or daughter in Brisbane, another one in Adelaide and Mum lives out in some small rural town, then being able to just monitor things for you to let you stay in your own home.*"
>
> "*Utilized in people that are in more rural and remote settings."*
>
> "*Fine tune the kind of cohorts who the system really helps the most…e.g., clients living alone, clients living with a family member who works during the day so home alone, clients with cognitive impairment, clients where the people that care for them are concerned about them living alone, clients who are getting close to needing full-time care/residential care."*
>
> *"Benefit for family members/family carers."*

The service provided also suggested that the technology could play a useful role in the assessment of a client's care needs and in determining their eligibility for services.

> *"And I think that the scope of this, you know, should be pushed out to ACAT assessors and RAS assessors and everyone who, at government funding level, who makes these decisions around, you know, the level of support that older people need within their own home."*

5.4 Case Examples of Actions Taken by Service Providers

Case Example 1

SSH system detected 8-9 days of meal preparation triggers followed by a further 4 days of transfer triggers. ACSPs contacted participant. Household member had had a progressive physical decline. This household member was the primary carer for the participant (who had cognitive decline). ACSP suggested that household member see GP. Service provider also arranged a referral to My Aged Care (MAC) requesting a re-assessment of the client and the client's household member to look at their eligibility for a higher level of HCP.

Case Example 2

SSH system detected ongoing transfer and mobility triggers. ACSP contacted participant. Transfer and mobility triggers started after the client fell at home. Participant reported feeling fine (but slow). Social groups and bus trips had also recently been cancelled by ACSP due to COVID. SSH system detected ongoing dressing, transfer, and mobility triggers. ACSP had regular contact with participant as triggers continued over an extended period. During one of these phone calls participant reported feeling lonely and the ACSP organised pastoral care visits. SSH system continued to detect ongoing dressing, transfer and mobility triggers. Service provider organised allied health reviews.

Case Example 3

SSH system detected 4 days of transfer triggers and ongoing dressing triggers. ACSP contacted the participant's carer. Participant had recently seen a specialist and condition was deteriorating but carer reported that there is "not much more they can do". ACSP discussed options for increased services. SSH continued detected ongoing triggers (for 13 days) with transfers, mobility and dressing. While ACSP was visiting client, they became very unwell, and ambulance was called. When client returned home some technical issues initially and then SSH detected triggers with transfers. Continued to have intermittent triggers in meal preparation, transfer and mobility (over 20-day period) but also technical issues, so hard to determine what was going on. Participant contacted service provider requesting increased services. Service provider commenced increased in-home respite, domestic assistance and organised for a walker to be repaired. Meals and hygiene assistance also offered but declined.

Case Example 4

SSH system detected mobility triggers for 3 days. Service provider contacted the participant. Participant reported feeling tired as had had a few drinks. Social work visit indicated concerns about a decline in the participants mental health. SSH system showed mobility triggers over 7 days and dressing triggers over 2 days (tech issues making it hard to get a clear picture). Service provider contacted participant who indicated they had been drinking a lot recently. SSH continued to detect ongoing dressing and mobility triggers (tech issues made it difficult to get a clear picture for client). Service provider offered the participant additional service (declined by participant). Ongoing meal prep and mobility triggers and service provider again offered additional services (declined by participant).

5.5 Case Study

The following case study outlines the presentation of one participant enrolled in a research trial using the SSH platform. This case study sets the scene for the successful use of SSH as a technology solution to support older people living in the community. Some details have been omitted to protect identities.

A participant of a CSIRO SSH research trial lived alone in the community. The participant was a recipient of an HCP – Level 1 (HCP1) with an ACSP. The participant was receiving their usual support from the ACSP (usual care) in addition to the daily monitoring provided by the SSH system.

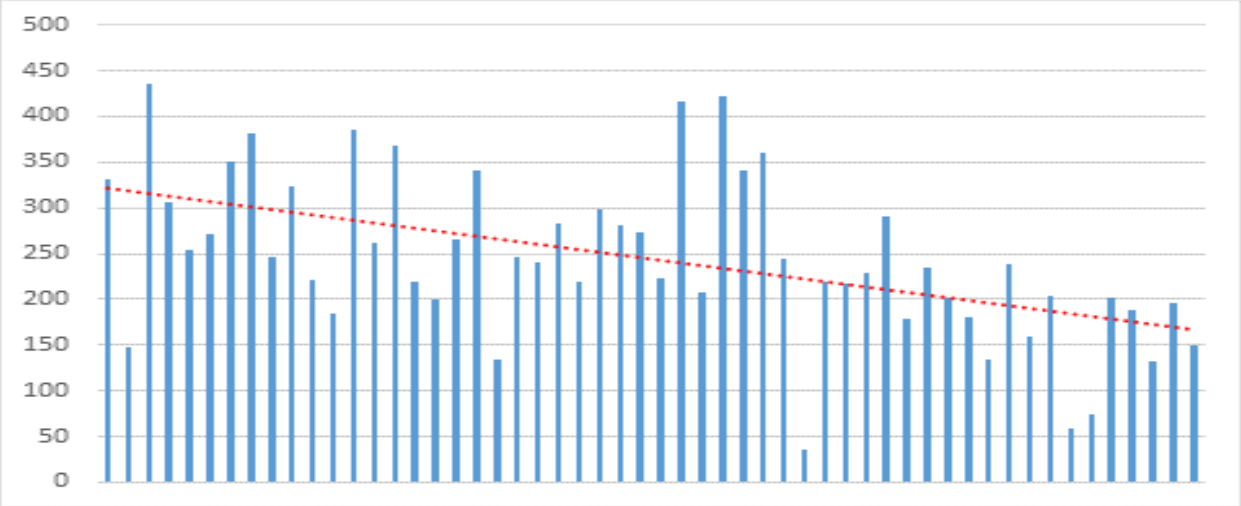

Figure 6. Mobility and function trend graph over 3 months.

Using the data from the SSH system, the ACSP noted a decline in the participant's mobility and function over a 3-month period (Figure 6). The ACSP became concerned about the progressive decline in the client's function and the clinical implications of this trend data. The ACSP initiated contact with the participant to discuss potentially increasing the level of their service provision. The following is an outline of facts and events of the situation:

- The participant was receiving fortnightly cleaning and fortnightly social support (shopping) through the HCP funding.
- The ACSP was monitoring the SSH provider platform daily, in addition to fortnightly visits provided through HCP funding.
- The ACSP became concerned about the trend in the client's mobility data (see Figure 1). The trend data showed functional decline on the SSH portal, and this data had deviated significantly from the client's normal level over the last 3 months.
- The ACSP reviewed the client's records, prompted by this review of the SSH platform. The ACSP noted that communication from a recent hospital admission had highlighted increased concerns for this participant and recommended a review of care levels.
- The participant's HCP case manager contacted the participant to check in on their situation.
- Additional checks by the ACSP found the following:
    - The HCP individual budget was reportedly fully allocated/expended in providing the current services.
    - The client had reportedly been awaiting a higher level of HCP for 6 months.

- The HCP case manager suggested taking up some additional services (for meal preparation and social support) through the CHSP on top of the current HCP. The participant had reportedly been approved for access to these services through the CHSP.
- The participant declined the suggested additional service provision due to the cost of the co-payment. At the time of the case study, this was a $10 co-contribution for each additional CHSP service episode. This contribution would have been in addition to any co-contribution that the participant may (or may not) already be paying towards their HCP.
- The ACSP explored whether there was a case for financial hardship (to allow them to waive the $10 co-payment).
- The provider was also exploring whether the information from the SSH system could be used to support an assessment/re-assessment (by ACAT) of the client's eligibility to expediate a higher level of HCP. It is unclear whether a referral had been made to ACAT to assess eligibility for this and what the outcome of this referral had been.
- During this period of exploring additional services, when one of the care workers from the ACSP visited the participant for fortnightly care provision, the participant did not answer the door. The participant was found unresponsive inside their home and was admitted to hospital.
- Checks of the SSH system confirmed that a sleep episode had occurred the night prior to the care worker attending the client's home. Additionally, the SSH system was able to confirm that the client had moved around the home the morning of the medical incident. The client later reported to care staff they thought they had been on floor for many days. Therefore, the SSH system was able to confirm that the participant had been on the floor for a maximum of 5 hours (the time between movement detected and the hospital admission via emergency services) and not days, as reported by the client to ambulance staff.

This case study provides an example of how the SSH monitoring system can be used to objectively demonstrate functional decline, to predict clinical deterioration, and to start care conversations between service providers and their clients. The case study also demonstrates the need for ACSPs to be able to intervene swiftly and flexibly to ensure their clients can access individualised, preventative, services in a timely way to avoid untoward incidents from occurring.

This report will continue to describe the showcase research trials that have supported understanding of the implementation of the SSH platform.

6 Conclusion

The randomised control trial described in this report describes the validation of a digital smart home technology aimed at assisting older adults receiving aged care services to remain in their own homes for longer. The study was undertaken in the Australian context with older adults receiving community aged care services support. The objective was to evaluate whether the addition of smart home technology can help maintain the functional abilities and quality of life of older adults and the potential impacts of this technology for both the older adults, carers, and the ACSPs.

The study showed that for older adults receiving an HCP package in the intervention group social care related quality of life was better (10 times less ASCOT score across the one year of measurement) compared to the Usual Care group. SSH only provided marginal benefits over the 12-month trial period for health-related quality of life (EQ5D) and functional independence (KatzADL). Neither group demonstrated a significant difference in relieving carer burden (Zarit ZBI-12).

The case studies, interviews and reviews of the service provider logs revealed the SSH system assisted in identifying health and functional decline of participants and that the ACSPs were able to act based on this data. Feedback from ACSPs highlighted the usefulness of the system in providing additional insights, more targeted care, and triggering more timely and in-depth care conversations. The ACSP comments highlighted some concerns including that the SSH system may provide a false sense of security, there was a need for re-baselining and the monitoring and maintenance of the system was quite resource heavy. The ACSPs also highlighted that their ability to act on the data to increase the participants' supports was limited at times (e.g., wait times in the aged care system for assessment and/or allocation of higher levels of support were long). Additionally, government level changes to the way/types of aged care services funded may be required to successfully implement the technology. Feedback from the participants indicated the SSH system was acceptable and provided a sense of reassurance, while some found it beneficial. However, the participants engaged minimally with the system during the trial and some concerns were raised about the lack of an emergency response.

SSH showed no difference in the overall healthcare utilisation cost from that of the UC group. SSH had no impact on cost savings. The disruptions of COVID-19 could have resulted in potential contamination of the healthcare utilisation data. Despite this, the analysis of cost-effectiveness was also limited by the timeframe of the trial (12 months) which may have been too short to realise any potential cost savings. An increased timeframe and longitudinal observation may have also been required to observe any potential changes in other outcome measures.

7 Opportunities Moving Forward

The DACS trial provided the opportunity to undertake a 12-month trial of the SSH technology in conjunction with several service providers. Inevitably there were many opportunities identified to improve the system to better support older people in Australia living in their homes and service providers supporting these people. Some of these opportunities are listed here.

- Work to increase user engagement with the system.
- Looking at the impact of SSH for non-resident family carers and service providers.
- Adding different sensors into the suite of offerings – e.g., wearables/measuring out of home supports, physiological monitoring (HR, HR variability, blood pressure, weight) other functional vital signs (grip strength, gait speed, 30 sec sit-stand, balance measures), speech biomarkers, more advanced activity detection.
- Using the different sensors and ground truth collection to strengthen the algorithms for ADL monitoring.
- Using predictive machine learning techniques to detect future functional decline.
- Looking at algorithms for combinations of sensor data and physiological monitoring (e.g., weight combined with meal preparation, heart rate combined with activity measures).
- Adding aged care normative values to the system (to give client, providers, family a sense of how someone is tracking compared to age-graded norms).
- Adding assistive technology to the system – voice assistance, falls prevention, GPS trackers, medication dispensers, exercise programs, socialisation/loneliness prevention programs, social robots, smart-lighting for falls prevention, smart-door locks, smart-door bells, memory apps/reminders.
- Using the sensors to create custom measurements, i.e., using door activity to measure house occupation.
- Working towards pathways for funding of technology services as mainstream, funded, lines of supportive care.
- ACSPs - conduct a co-design piece with ACSPs to redesign the interface system. It became apparent as the studies progressed that “trends” are likely to be more important to the ACSPs than the traffic lights of green, orange, and red faces. This information was available in the back end of the system – but the way the system was set up it was not easily accessible to ACSPs. In some cases, ACSPs requested this data from CSIRO to give them a better idea of what was going on.
- Opportunities to address workforce challenges – technology like SSH may have the ability to significantly reduce travel time for care staff which could mean a redistribution of staff to other needed work activities.

8 Acknowledgement

The authors wish to acknowledge:

- The Australian Government for its funding of this project through its Dementia and Aged Care Services Research and Innovation funding.
- The CSIRO eHealth Research Program for the provision of additional funds to support the scientific objectives of the project.
- Professor Michael Fine and Macquarie University for contribution towards data analysis.
- Associate Professor Joshua Byrnes and Griffith University, Qld for contribution towards health economics data analysis.
- The aged care service partners and their clients who contributed to data collection – Anglicare Southern Queensland, integratedLiving Australia, All About Living.

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