Independent evaluation of ARMED service: final report.

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Independent Evaluation of ARMED Service

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Executive summary

Introduction

ARMED (HAS Technology, Lichfield, UK) is a falls prevention technology that combines a wrist-worn activity tracker with predictive analytics and machine learning to enable early intervention. Data from the tracker is augmented by weekly grip strength and body composition measurements. ARMED-in-a-box is a streamlined version of ARMED that does not use the grip strength or body composition measures, rolled-out in response to the COVID-19 pandemic.

This independent evaluation was commissioned by the Digital Health and Care Innovation Centre and conducted by an interdisciplinary team from Robert Gordon University, the University of Aberdeen, and NHS Grampian. The purpose of the evaluation was to inform the potential for scalability of ARMED within the Scottish digital health and care context, and specifically to analyse and appraise the effectiveness of the current ARMED service and business models, aligning with the national technology enabled care (TEC) programme's existing test of change (TOC) activity.

Methods

We used a multi-method approach, conducted in four non-sequential, interlinked phases, between October 2020 and June 2021. Our planned methods had to be adapted, largely as a result of conducting the evaluation during the COVID-19 pandemic. There was limited availability of data from TOC sites on which to conduct analysis, as a result of delays to projects at these sites due to reprioritisation of local resources during the pandemic. Although additional (non-TOC) sites were initially enthusiastic to participate in the evaluation, they did not provide any data. Recruitment of interview participants was also challenging, due to the smaller than anticipated potential pool of people with experience of using ARMED, and the impact of the COVID-19 pandemic on staff capacity to take part in the evaluation and to assist with recruitment.

Phase 1: ARMED Evaluation comprised quantitative and qualitative components. The quantitative component featured four informal case reports obtained from TOC sites, one scaled-down interim report, and anonymised data obtained directly from HAS Technology evaluating ARMED with 57 older adults. Model based cost-effective analyses were planned but could not be completed due to insufficient data.

The qualitative component featured interviews with 24 staff members from TOC and non-TOC sites that had used ARMED, and four older adults who were users of ARMED. Interviews explored experiences and perceptions of using ARMED to understand feasibility, acceptability, perceived effectiveness and value of ARMED. We also interpreted the interviews through the lens of the NASSS (non-adoption, abandonment, scale-up, spread, sustainability) Framework (Greenhalgh et al, 2017).

Phase 2: Landscape Review comprised a rapid scoping review, informed by JBI methodology, to identify and undertake a high-level assessment of technologies similar to ARMED.

Phase 3: Service deployment model review was conducted in two phases and aimed to identify if there is an optimum service model for the deployment of ARMED, and to assess the current impact and efficiency of ARMED in a real-world setting. Data were interpreted in relation to the innovation-decision process proposed by Rogers (2003) which traces the stages of knowledge, persuasion, decision, implementation and confirmation.

Phase 4: Business model review comprised internet-based searching, information from the HAS Technology white paper, interview data, and an additional interview with a HAS Director. Data were interpreted in relation to the Osterwalder and Pigneur (2010) business model canvas concept (BMC), with the interviews based on questions associated with each of the nine building blocks of the BMC.

Key Findings

ARMED is a novel technology, evidenced by there being few comparable services, with only one highly similar technology identified as being available on the UK market and conforming with the Medical Devices Directive. It therefore has the potential to lead the way in addressing an important and costly health issue (falls), as well as supporting the wider agenda around early intervention and independent living.

We were not able to determine ARMED's impact on falls prevention or to make recommendations on its scaleability, due to the lack of available data, owing to the evaluation sites being at an early stage in the adoption decision process. We were able to determine that, in a small sample of users, modest health benefits were suggested for some participants, and that ARMED was generally perceived positively by those users. Both staff and ARMED users viewed ARMED as effective for promoting physical activity, monitoring sleep and facilitating collaboration (staff-to-staff & staff-to-service user). Participants could also see the potential for ARMED to prevent falls, frailty and hospital admissions, but felt that further development and longer evaluations are required to fully evaluate

the impact of ARMED on these outcomes. We identified several positive examples of the use of ARMED in health and care settings, but technical and usability issues and resource requirements suggest that ARMED is not currently suitable for widespread adoption in these settings. The highly staff-intensive nature of ARMED as implemented by the sites included in this evaluation may render its adoption prohibitive for many services.

The service deployment model review identified that ARMED currently faces challenges at the persuasion stage in the adoption decision process, due to issues with compatibility and complexity. Interpretation of the findings through the NASSS Framework lens also identified that there are complicated and complex issues to be resolved before ARMED can be considered for adoption at scale, borne out by the number of sites in our evaluation that had abandoned trials and not progressed to a decision to adopt.

We were not able to recommend an optimal service model for ARMED, in light of the user experiences and stage of adoption at the included sites. Rather, we have made a set of preliminary recommendations for increasing the potential for wider adoption of the ARMED service.

Participants viewed ARMED's emphasis on falls prevention as an attractive value proposition, with potential to deliver cost and time savings and to support self-management and the maintenance of independence. However, the technical difficulties encountered by many of the sites in this evaluation seem to be a key barrier to realising the value of the ARMED service.

We have identified several aspects of the business model that HAS technology could review in order to move towards scale-up, including refining the value proposition for specific customer segments; considering widening the partnership base to include other hardware providers (e.g., trackers/watches); considering the value proposition and business model for ARMED and ARMED-in-a-box, and redesigning after-sales support for delivery at scale and the pricing model.

Recommendations
For Policy

The findings of this evaluation suggest that the ARMED service has potential, but is not currently ready for adoption at scale within the Scottish digital health and care context. Recommendations are made below for further development of the ARMED service and to increase readiness of services to adopt ARMED, or other similar types of technologies.

Learning generated by conducting this evaluation has informed the recommendation that when pursuing adoption at scale of remote health monitoring technologies such as ARMED, the following should be ensured: (i) the technology has been thoroughly and rigorously tested (and refined where appropriate) with the intended users and in the intended service settings and contexts. We recommend that a checklist is developed for this purpose; (ii) independent evaluation of readiness for adoption should be conducted. We recommend that a standardised assessment is developed specifically for the Scottish Digital Health & Care context; (iii) robust and standardised evaluation designs should be used at each test site to ensure consistency of data for analysis. Specific recommendations for future evaluations are detailed below.

For HAS Technology/ARMED

Recommendation 1

Ways of simplifying the technology aspects of ARMED should be explored to reduce the current challenges of charging and syncing multiple devices, and particularly to reduce the burden on staff and resourcing for deploying ARMED with clients who are unfamiliar with the technology and /or who struggle to gain familiarity and engage with it. This would support adherence and confidence in the technology.

Recommendation 2

Clearer and more user-friendly technical support and guidance on set-up and ongoing use should be provided to all individuals and staff using ARMED, including hardware, software and data management. This guidance and support need to be accessible, timely and appropriate for all users (individuals and staff). Furthermore, thought needs to be given to how this could be provided at scale, and in formats that are most appropriate for each health and care setting. Options that could be explored include a web-based source of information, user manuals/instructions (including video guidance on specific aspects of ARMED set-up and usage), and frequently asked questions on technical issues, with the option of accessing technical support staff where required.

Recommendation 3

Difficulties around accessing and interpreting the data need to be addressed, in order for ARMED users (individuals and staff) to engage in the full functionality of ARMED and for it to be used for its intended purpose i.e., fall prevention.

Recommendation 4

Ways of converting the manual process of uploading grip strength and body composition measures to an automated process should be explored, in order to reduce staff workload and the risk of errors in data entry.

Recommendation 5

The potential should be explored for ARMED to be deployed for a wider range of purposes beyond its initial application for fall prevention. For example, its potential for application among people with learning disabilities living in sheltered accommodation could be further investigated. In pursuing this, care will need to be taken to ensure that the specific value proposition of ARMED for each customer segment is clearly identified and communicated. Likewise, marketing, sales, and after sales processes will need to be appropriately designed for each customer segment.

Recommendation 6

Ways of introducing the ARMED technology gradually to users should be explored in order to ensure they can understand its purpose and be comfortable using it, and in order to increase the likelihood of adoption. Examples of effective strategies could be collected from staff and users, and shared as part of the user guidance and support.

Recommendation 7

The pricing model should be reviewed to ensure that the ongoing costs of using ARMED are not prohibitive to a service adopting it.

Recommendation 8

A clear and distinct value proposition for ARMED-in-a-box should be identified and articulated, with each element of the business model developed for this offering.

Recommendation 9

Eligibility for funding opportunities, should be explored, such as a Management Knowledge Transfer Partnership (KTP), to help refine and robustly test the ARMED business model and prepare the service for delivery at scale.

For Services

Recommendation 1

Services need to allow sufficient time for familiarisation, training, set-up and implementation of ARMED, in order for staff and service users to understand its intended purpose, to feel comfortable using it and to have confidence in ARMED. This is particularly important for service users and staff who are less familiar with technology.

Recommendation 2

Services need to ensure adequate staff resource is available before attempting to implement ARMED in their setting. A dedicated staff member with a remit to lead on ARMED is advisable.

Recommendation 3

Services need to carefully consider the appropriateness of their client group for ARMED, including their ability to interact with the technology and to use it independently, their willingness to use it and their potential to benefit from ARMED.

Recommendation 4

When considering testing ARMED in a service, consideration needs to be given to appropriate baseline measures (e.g., falls rates) and to routinely gathering data that can be used to evaluate the impact of ARMED.

Recommendations for future evaluations

We were able to generate evidence on some aspects of ARMED, such as feasibility and acceptability, but not on effectiveness or cost-effectiveness and we are unable to recommend widescale adoption of ARMED at this time. In order to do so further robust evaluation should be undertaken and should include:

- Standardisation of data collection with agreed valid, reliable and logistically feasible measures to facilitate pooling of data from different sites using ARMED.
- The use of valid measures of the constructs of interest (e.g., physical: balance, mobility; psychological: balance confidence, activity avoidance) which are carefully selected and matched with tests that provide assessment of the construct.
- The use of reliable tests that include minimal variation over short periods of time. Attention should also be paid to implementing protocols to maximise reliability (e.g., timing of tests, instructions provided, equipment used, measurement of multiple tests with averages taken) Prior to roll-out of tests, the scientific literature should be reviewed to determine if tests have appropriate reliability with the population of interest, or pilot testing may be considered.
- The use of measures included in scientific literature, in order for comparisons with similar population and technologies to be made.

- Ensuring that testing batteries are logistically feasible, taking into consideration the physical and emotional stress they place on participants, and that staff have capacity to complete testing batteries at regular intervals. This will enhance compliance and minimise drop-out across evaluation sites.
- Collection of baseline measures (e.g., falls rates) and sociodemographic variables of samples before ARMED is implemented.
- Larger and longer evaluations that are designed to evaluate effectiveness and cost-effectiveness e.g., adequately powered randomised controlled trial comparing ARMED with usual care, with collection of pre-intervention, post-intervention and follow-up measures and cost data regarding equipment costs, cost of support from ARMED, and costs of staff time.
- Comprehensive exploration of barriers to adoption at all levels e.g., technical, service-level, supply chain.

Table of Contents

Abbreviations

Abbreviation/Term	Definition
ARMED	Advanced Risk Modelling for Early Detection
DHI	Digital Health and Care Innovation Centre
BMC	Business Model Canvas
HSCP	Health and Social Care Partnership
MDD	Medical Devices Directive
NASSS	Non-adoption, abandonment, scale-up, spread, sustainability
RA	Research Assistant
RGU	Robert Gordon University
TEC	Technology Enabled Care
TOC	Test of Change

1.0: Background and Purpose of the Evaluation

1.1: Purpose of the evaluation

This independent evaluation was conducted during September 2020 – June 2021 by an interdisciplinary team of clinical and academic researchers from the health and business disciplines based at Robert Gordon University (RGU), the University of Aberdeen and NHS Grampian. It was commissioned by the Digital Health and Care Innovation Centre (DHI) to inform the potential for scalability of the ARMED (Advanced Risk Modelling for early Detection) anti-fall solution within the Scottish digital health and care context, in keeping with Scotland's Economic, Economic Recovery and Digital Heath and Care strategies, Technology Enabled Care (TEC) Delivery Plan, and National falls and fracture prevention strategy.[1] Specifically, the evaluation aimed to analyse and appraise the effectiveness of the current ARMED service and business models, aligning with the national TEC programme's existing test of change (TOC) activity.

The requirements of the commission were to:

1. Conduct a review and evaluation of the evidence base on the practical efficiency of the current ARMED service, including a measurement of benefits and impacts on a service and systems level.
2. Conduct a UK landscape review to identify and undertake a high-level assessment of similar products/services to ARMED, ensuring that as far as possible a like-for-like comparison is made.
3. Conduct an options appraisal to identify if there is an optimum service model based on the current deployments of ARMED.
4. Analyse the current ARMED business model to assess appropriateness and affordability for Scotland's health and care sector.

1.2 Overview of ARMED in Scotland

ARMED, developed by HAS Technology (Lichfield, UK) combines wearable technology, predictive analytics and machine learning to enable early intervention to support independent living.[2] ARMED consists of a wrist-mounted wearable (Polar device) which continuously collects data from the user and uploads it to a mobile device. This data is augmented by regular (e.g., weekly) body composition (using biometric scales) and grip strength measurements. The data is used for predictive modelling and initiating alerts regarding inactivity,

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[1] Digital Health & Care Institute. Call for Proposals. Review and Evaluation of ARMED Service, June 2020
[2] https://www.hastechnology.com/armed-falls-prevention

irregular heart rate, restless sleep, dehydration and changes in body composition, all of which can be indicative of an increased risk of falling. The user receives alerts (vibration via Polar loop on wrist) to prompt physical activity, and family, carers, and /or healthcare professionals can receive notifications (by email) if the device is not being worn. Alerts are also sent to healthcare providers allowing them to intervene in a timely manner. ARMED data can be made available to healthcare professionals via a dashboard, allowing them to view current and historical data, including risk scores which are calculated daily. Information is also made available to ARMED users via a mobile application (app). ARMED is designed to identify gradual deterioration, so that interventions can be initiated to prevent crises such as falls and hospital admissions.
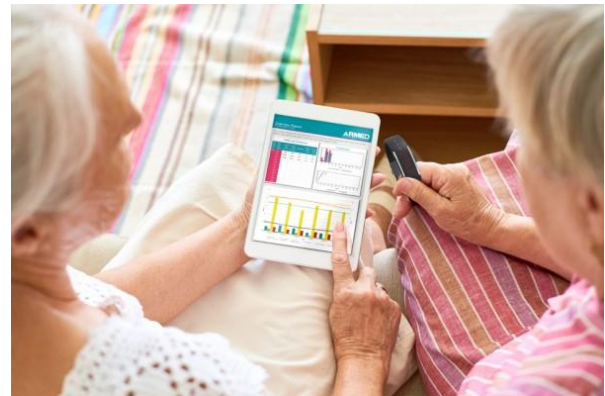
Figure 1 ARMED in use

Source: HAS Technology - https://www.hastechnology.com/armed-falls-prevention

In response to the impact of COVID-19 a streamlined version, "ARMED-in-a-box", was made available. ARMED-in-a-box consists of the Polar device, a mobile phone and SIM card, and provides access to the reporting dashboard and alerts. No body composition or grip strength measurements are required with ARMED-in-a-box, and it is sold as "ready to go".[3]

ARMED has been used in five TOC areas in Scotland, all situated in Health and Social Care Partnerships (HSCPs) and supported by the National TEC Programme. It has also been independently purchased by a number of other Scottish HSCPs. We aimed to include these sites in our evaluation.

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[3] https://www.hastechnology.com/armed-in-a-box

1.3 Structure of the Report

The evaluation featured a multi-method approach, conducted as four interlinked non-sequential phases, and is presented as four phases which map to the deliverables required to address the respective requirements stated above, namely:

Phase 1: ARMED Review: a mixed-methods evaluation of the practical efficiency, benefits and impacts of ARMED (section 2)

Phase 2: UK landscape review of products similar to ARMED (section 3)

Phase 3: Service deployment review (Options appraisal) (section 4)

Phase 4: Analysis of current ARMED business model (section 5)

Each section of the evaluation details the methods undertaken and the findings and recommendations for that phase. Section 6 synthesises the findings from all four phases, interpreting the findings through the lens of the NASSS (Non-adoption, Abandonment, Scale-up, Spread, and Sustainability) framework (Greenhalgh et al, 2017). Recommendations for further development of ARMED and for future evaluations are also made in Section 6.

2.0: Review of ARMED

2.1 Methods

We planned a mixed-methods evaluation to be completed over a six-month period (October 2020 – March 2021), to evaluate the impacts, benefits and cost benefits of ARMED on services and systems. We aimed to include all five TOC sites, two additional HSCPs known to have purchased ARMED independently, and one English housing association (Table 1). There were three planned components to the evaluation: (i) quantitative; (ii) cost-effectiveness, and (iii) qualitative. Here we provide an overview of the planned methodology for each component, along with amendments which had to be made, largely due to the impact of COVID-19 on availability of data and participants. We contacted the chair of the North of Scotland Research Ethics Committee who advised that NHS ethical approval was not required for the quantitative evaluation, as it was considered a service evaluation. NHS ethical approval would have been required to recruit users of ARMED from clinical settings (i.e., identified due to being recipients of a clinical service). We did not seek this approval, due to COVID-19

studies being prioritised by ethics committees at the time of planning the evaluation and the short timescale in which to conduct it; we therefore did not directly recruit patients via NHS clinical services. For governance purposes, we sought approval from the RGU School of Health Sciences Research Ethics Committee, with approval granted on 19.11.2020 (Ref: SHS/20/43).

Table 1 Proposed evaluation sites

Proposed Site	Description
Aberdeen City HSCP	TOC site
Argyll & Bute HSCP	TOC site
Dumfries & Galloway HSCP	TOC site
East Renfrewshire HSCP	Non-TOC site
Fife HSCP	TOC site
Inverclyde HSCP	Non-TOC site
West Dumbarton HSCP	TOC site
WDH	Social housing provider, West Yorkshire

Key: HSCP=health & social care partnership; TOC=test of change; WDH = Wakefield & District Housing Limited

2.1.1 Quantitative evaluation

The planned quantitative evaluation of ARMED was based on collection of pre- and post-intervention data comprising: 1) Falls data: number of falls, number of falls with injury, number of falls resulting in unscheduled hospital admission, number of falls resulting in mortality, consequences of falls (activity limitations/participation restrictions); 2) Implementation data: time required by the service and staff to implement ARMED, accuracy of alerts and levels of alerts raised by ARMED, adherence to ARMED requirements by participants (wearing Polar device, charging Polar and mobile devices), adherence to weekly measurements (biometric scales and grip strength); and 3) Outcome data: change in measures collected for ARMED purposes (grip strength, muscle mass, inactivity stamps, sleep quality, physical activity), hospital admissions, healthcare utilisation (e.g. GP visits, occupational therapy, physiotherapy).

Data were to be used to evaluate group-based and individual-based changes and establish cost effectiveness through a two-stage modelling-based economic evaluation. Due to restrictions imposed by COVID-19, proposed recruitment sites were unable to maintain or initiate ARMED interventions, such that the volume of

data required for planned quantitative analyses were not possible. Instead, four sites conducted informal case reports and one site conducted a scaled down interim report. Summaries of their findings were obtained and are presented in section 2.2.1 and 2.2.2 respectively. In addition, data were obtained directly from ARMED including representative customer metadata (e.g., step count, calories consumed) and a small pilot study investigating customer changes in subjective response regarding the ARMED service. Analysis of these data are presented in section 2.2.1. We endeavoured to obtain additional data from other sites known to have used ARMED, and communicated with several such sites. Despite initial enthusiasm from some, no additional sites agreed to take part in the evaluation.

2.1.2 Cost effectiveness evaluation

We had planned a modelling-based cost effectiveness evaluation. However, due to the limited amount of data obtained and lack of true baseline measurements assessing participants' falls, suitable estimates of the effectiveness of the ARMED service to reduce falls and identify potential moderating factors could not be developed. Without these estimates valid cost effectiveness modelling could not be achieved.

2.1.3 Qualitative evaluation

We planned to explore feasibility, acceptability, perceived effectiveness and value for money of ARMED and its service delivery model via interviews or focus groups with the following stakeholders: people who have used ARMED, family members of people who have used ARMED (where alerts have been sent to family members), staff in TOC sites where ARMED has been used, staff in other (non-TOC) sites where ARMED has been used. Our planned recruitment strategy was to identify participants via TOC collaborative members, and key contacts in the three non-TOC sites, where they agreed to take part in the evaluation. Our target sample size was 40 (16 ARMED users, 24 staff). Recruitment was challenging; there appeared to be interest in the evaluation from TOC collaborative members and other key contacts, but agreement to participate often did not materialise even after prolonged communications with several evaluation team members. We employed reminders, offered informal telephone-calls and proposed a range of ways to take part (1-1 or group interview by Teams or telephone; providing written feedback by email). We were helpfully introduced to additional contacts by HAS technology staff, who identified individuals and sites that they were/had been supporting to trial ARMED. Unfortunately, this only resulted in one participant agreeing to take part (older adult user of ARMED). Despite an enhanced recruitment strategy, we did not

reach our target sample size; we did however successfully recruit and interview 26 participants (4 ARMED users and 22 staff). Several factors are likely to have impacted on recruitment. The evaluation was taking place during the second wave of the COVID-19 pandemic, which will have affected capacity of staff in TOC and other sites to engage with the evaluation. The impact of COVID-19 on the TOC projects themselves, most of which were halted for a period, resulted in a much smaller pool of potential participants (both people who had used ARMED and staff who had experienced it being implemented in their setting).

Data were collected via Teams or telephone interview, either 1-1 or in small groups with the participant/s and one of two research assistants (RAs) attached to this evaluation. Flexibility of being interviewed alone or with others was intended to facilitate participation. All participants provided verbal informed consent to take part, after reading a detailed participant information sheet. A topic guide was used to ensure consistency across interviews and RAs, and all interviews were recorded and transcribed intelligently (i.e., light editing and eliminating of irrelevant utterances). Data were analysed using the framework method (Ritchie and Spencer, 1994), commonly used in applied health research and evaluation. The qualitative evaluation lead (KC) and both RAs were involved in analysing the data to ensure rigour.

2.2 Results

2.2.1 Quantitative Evaluation of ARMED

I) Case Study Reports

Case study reports were produced and subsequently obtained from four sites (Argyll & Bute; Fife; Dumfries & Galloway; East Renfrewshire) describing the experiences of participants (range 1 to 7) during an ARMED intervention. These case study reports were obtained from sites where more formal data were to be obtained but was not possible due to changes in service in response to COVID-19. Information most relevant to the present evaluation were extracted with additional summary information provided for context. All available information regarding falls, physical fitness, body composition and sleep hygiene was extracted and presented largely in accordance with the original reports.

Argyll & Bute

Argyll & Bute used ARMED in a community reablement service setting with service users living in their own homes. For one year in Argyll & Bute there were 9,793 occupied bed days due to falls with an estimated cost of £5,889,302. ARMED was selected as it was believed the technology had the potential to increase activity, encourage self-management, enable the monitoring of crucial

periods of transitioning from hospital to home and ultimately could reduce falls and readmission to hospital.

Case study: An 89-year-old female agreed to take part in the pilot. The participant had fallen previously and had lost confidence. Daily steps were monitored and showed a clear increase over a 4-week period of data collection. The participant's sleep pattern was monitored and demonstrated overall improvement with only two nights of relatively poor sleep. Inactivity also reduced over the same period of capturing data. The participant's self-report highlighted the benefit of the ARMED technology to increase mobility and decrease periods of inactivity.

Fife

Fife used ARMED in a supported accommodation setting. CHARM (Continuous Health, Activity and Routine Monitoring) was a pilot run by Fife Council in partnership with NHS Fife. CHARM follows a person-centred approach and involves user volunteers wearing the Polar device, participating in a weekly weigh-in, hand grip assessment and wellbeing surveys. With funding in place, the pilot was planned to run for three months from January 2019 for both NHS Fife and Fife Council users.

Case study: Data were collected from 7 participants demonstrating a slight reduction in average weight (- 0.2kg). Individually, three users increased their weight (+0.3 to +3.7 kg), but data showed this gain to be an increase in muscle mass, bone mass and body water - with a reduction in body fat. The remaining four users all recorded weight loss (-1.2 to -3.7 kg). There was also a positive change in average body composition with body and visceral fat down by 1.9 and 0.5 %, respectively. Bone mass, body water and muscle mass increased by 0.1 kg, 1.3 and 1.3 %, respectively. These results were supported by an increase in grip strength (+3.6 kg) and reduction in metabolic age (-2.5 years). The follow-up also included a wellbeing survey (responses ranging from 1-10) which indicated that user perception showed a small increase in how they viewed their wellbeing (+0.3), moving around during the day (+0.2) and fluid consumption (+0.6) since May 2019.

Formal falls information was collected prior to and during the pilot. Results showed falls status to remain consistent such that those who fell prior to the pilot also fell during the pilot, and those that did not fall prior did not fall during the pilot. Frequency of alerts was monitored. Two users received no alerts (7,000 + steps per day). One user received 4 alerts (10% of available days of data). On each occasion there was a reasonable explanation why the user had lower physical activity than usual. Five users received alerts 58-85% of days and

were the least active (<3,100 steps a day). The ability to raise accurate alerts on a more personal level was not sufficiently clear. An unreasonable amount of time was required to identify what had changed in pattern of behaviour. There were often no discernible changes in data or clarification following the alert email.

Dumfries & Galloway

Dumfries & Galloway have used ARMED in a variety of settings including overnight support for adults with learning disabilities, residential homes for older adults and responder services for older adults.

Case Study: The success of ARMED was evaluated with two participants regarding overnight support, with ARMED used to evaluate the activity patterns of individuals.

Participant 1: Monitoring with ARMED established that the participant often stayed up all night watching the TV, returning to their bed in the morning, with the sleepover staff member being unaware of this. Alerts were set-up via Just Roaming (part of Just Checking, motion-sensor based technology for remote monitoring) to ensure that a check/conversation took place with the participant if it got to half past eleven and they were still up. The sleepover staff member was then reminded to encourage the participant to go to bed, which worked well.

Participant 2: Prior to the start of the test, staff were concerned that this participant was napping throughout the day and was requiring support from the waking overnight staff as a result. Data obtained from the polar bands supported the concerns of staff, and as a result the participant's care plan was adapted.

East Renfrewshire

East Renfrewshire used ARMED in a community reablement setting, with service users living in supported accommodation or their own homes. Evaluation was planned for 40 participants but had to be scaled back to 15 due to delays in receiving equipment and technical issues surrounding syncing. The average age of the participants was 85 and ranged from 75 to 92 and comprised four individuals who were categorised as frequent fallers. A case study summary was implemented for three participants.

Participant 1: The initial data report showed Mrs X had high activity levels throughout the day and showed healthy sleep hygiene. She agreed her activity levels were high and reported she enjoys her garden and carrying out household chores. She did not agree that her step-count/movement was excessive and did

not feel fatigued. Mrs X has always maintained an active daily routine throughout her life and hopes to continue this. Outcome: The participant was reassured by the data and was keen to maintain the programme. High activity levels indicated to the practitioner that visits could potentially be reduced as he was satisfied Mrs X was coping well.

Participant 2: Data received in the reports from ARMED showing Mr Y's movement throughout the day and his sleep pattern showed he was having significant periods of inactivity and low step-count. This indicated that this level of inactivity could cause a potential risk. These risks may be in reducing muscle tone, general physical deconditioning and disrupted sleep pattern. To make a positive intervention, the Practitioner visited Mr Y and read over the ARMED report with him. Mr Y agreed he maintained healthy sleep hygiene; however, he was unaware of the inactive periods he was having during the day as he was going out for a daily walk in his local area and doing some household chores. Following a discussion, he recognised that he was spending long periods of time watching the TV or on social media. It was agreed that it would be beneficial for him to slightly increase his step count during the day. Outcome: Since taking part in the ARMED Project Mr Y's mobility improved after being shown the data and felt being part of the trial had a positive benefit to him. The programme developed with the client from the data received can potentially reduce the amount of home visits as the data can be monitored and the client updated by telephone of how they are progressing. This is especially relevant during the COVID-19 crisis.

Participant 3: The data received indicated Mrs Z was maintaining a good level of activity throughout the day. She was consistently meeting the step-count range set by the system and prompts were helping to reduce periods of inactivity. There was a positive increase in Mrs Z's confidence in walking outdoors and she had no problems ascending/descending the communal stairs to her first floor flat. The data consistently indicated Mrs Z having periods of inactivity and when discussed, these were the periods she identified as feelings of lethargy. The risks of inactivity were discussed, particularly with regard to falls. A programme was established to help recognise the inactivity levels and increase activity to help maintain muscle and bone strength. Outcome: Mrs Z began using phone data to increase her step-count and going out daily. She also began monitoring her sleep pattern with the phone app and adapting her behaviour to improve sleep hygiene. The data helped the practitioner develop a programme the client could work on, helping improve her mobility and confidence.

II) M Power

A three-month interim report was obtained evaluating ARMED in Dumfries & Galloway. The analysis comprised data collected pre-intervention and 12-weeks into the intervention from 27 participants aged 65 and over with at least one long-term health condition who were categorised as at risk of falls. Nine of the participants were living in residential care, 11 were referred from a reablement service, and 7 were receiving care at home and responder services. The analysis conducted on the 27 participants between pre and 12-weeks reported the following:

- 52% exhibited lower levels of daytime inactivity
- 52% increased step count
- 85% maintained or improved risk levels
- 82% maintained or improved confidence in their ability to manage long-term conditions (26% improved; 56% maintained)
- 85% maintained or increased in feelings of safety to live independently
- 74% reported a maintained or reported improved sense of satisfaction with life as a whole
- 15% reported a fall
- 96% maintained or improved Rockwood frailty score (27% improved; 69% maintained score)

III) Analysis of ARMED Sample

Two data sets were obtained directly from ARMED comprising anonymised data collected from representative elderly customers suffering from long-term conditions undergoing an ARMED intervention. Long-term conditions included diabetes, arthritis, high blood pressure, fibromyalgia, cancer and depression. The first data set included high frequency measurements from 45 participants including daily activity, calories expended, body composition and grip strength. Analyses were performed by splitting participants' measurements into four equal time periods and calculating group-based effect sizes (standardised mean difference) and individual auto-correlated regressions to establish the linear trend across the entire monitoring period. Analyses were restricted to participants that provided a minimum of 20 data points to ensure representativeness and enable appropriate smoothing of the data. Twenty-four participants provided sufficient data with a median of 35 data points (IQR: 23 to 61) over a median period of 113 days (IQR: 74 to 124 days). Results from group- and individual-based analyses for each of the variables measured are presented below.

The second set of data included baseline and two-month post-intervention questionnaire responses from 12 participants comprising self-reported fall, exercise, daily mobility, and sleep hygiene evaluations. Based on the limited number of data points available, simple descriptive summaries of the change in variables across the intervention were included.

High frequency data

Summaries of the high frequency data from 24 participants illustrating the distribution of calories expended, steps and risk scores are presented in Figure 2. Group based effect sizes were calculated relative to data collected in the first quarter. Consistent results were obtained for calories expended and steps, with trivial to small decreases identified (calories: -0.01 to −0.29; steps: -0.19 to −0.08). Similarly, trivial to moderate increases in risk scores were identified (0.04 to 0.12). These group-based calculations highlight that outcome measures are reflective of the healthiest behaviours in the first quarter of the intervention
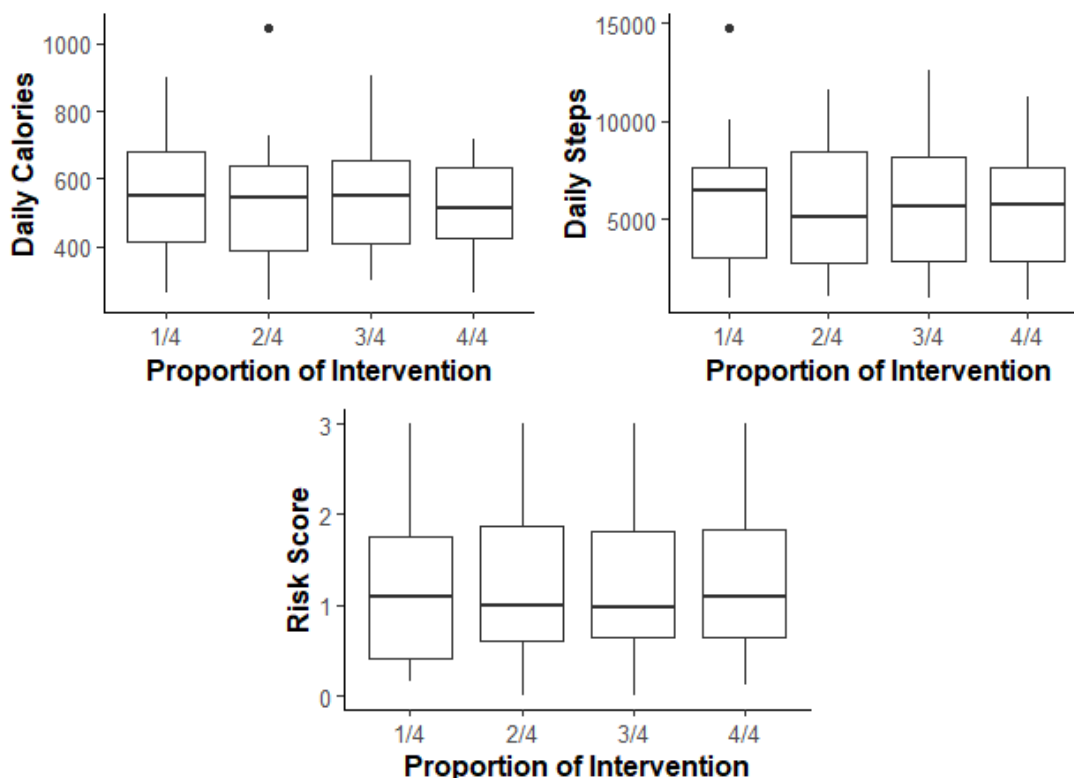
Figure 2: Distribution of calories (top left), steps (top right), and risk score (bottom) of participants from the first data source separated into four equal time periods across intervention.

and experience subsequent deterioration. As data were not collected prior to the intervention, it is possible that early values reflect an immediate impulse from engaging in the intervention.

Distribution of individual linear trends (describing the daily change) of calories expended, steps and risk score are presented in figure 3. The analysis demonstrated that approximately 75% of individuals exhibited a negative trend for calories expended and steps. The median decrease was 6 calories and 10 steps per day from the start of the intervention. In contrast, change in risk score was more evenly distributed with approximately 50% exhibiting increases and 50% exhibiting decreases.
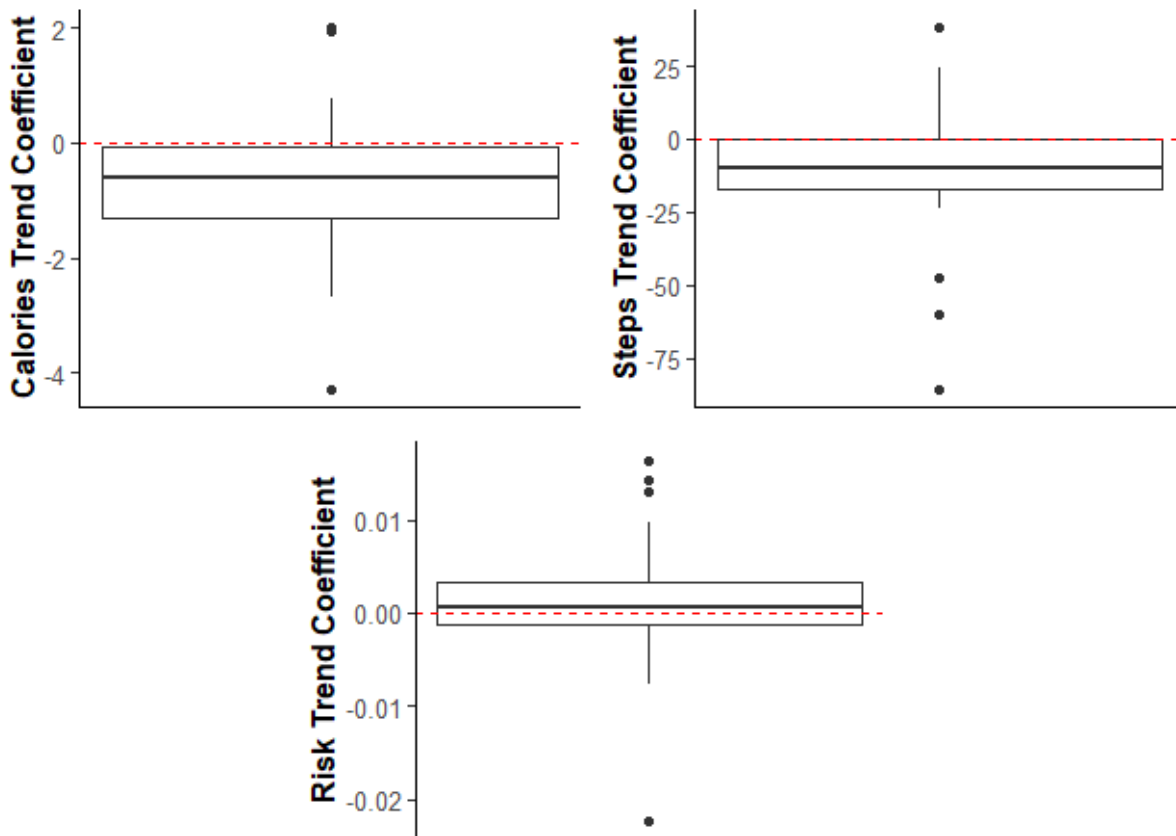

Figure 3: Distribution of calories (top left), steps (top right), and risk score (bottom) linear trend coefficients of participants from the first data source

Pre-Post questionnaire data

Of the 12 participants with pre- and post-intervention data, four experienced a fall in the 6-months before the intervention, with one of the participants experiencing four falls in that period. During the 2-month ARMED intervention, only one participant who had not experienced a fall in the previous period reported falling.

Among the questions asked, participants were requested to answer the following on a scale of 1 (Strongly disagree) to 10 (Strongly agree). 1) Healthy lifestyle: All things considered, I live a healthy lifestyle; 2) Daily mobility: I get up and move around regularly during the day; 3) Regular exercise: I take regular exercise; and 4) Sleep hygiene: I sleep well most nights. The median values and interquartile ranges of the change scores (post-intervention minus pre-intervention) provided evidence of improvements in participants self-rated perceptions:

- Healthy lifestyle change: 2 (1 to 4)
- Daily mobility change: 1.5 (0.75 to 4.25)
- Regular exercise change: 2.5 (1 to 3.25)
- Sleep hygiene change: 1 (0 to 3.25)

Summary & Conclusion

Due to the limited use of ARMED at proposed recruitment sites, and difficulty recruiting additional sites, there was limited data with which to evaluate the benefits and impact or ARMED, and none to address cost-effectiveness. The reports and data presented above suggest modest health benefits for some participants, and that ARMED is generally perceived positively by the users concerned. The data suggest that the largest benefits may occur in the early phase of using ARMED, with subsequent declines in health behaviours back towards baseline levels. This trend is in keeping with the evidence for step-count monitoring interventions, where a recent systematic review found the largest increase in step count at ≤4-months (Chaudhry et al, 2020). The lack of data on falls specifically was a major limitation to this part of the evaluation. Given the limited data obtained, it is not possible to draw conclusions on ARMED's impact on falls prevention.

2.2.2 Qualitative evaluation of ARMED

I) Description of Participants

Twenty-six participants (10 male, 16 female) took part in the evaluation.

Four were older adults (2 male, 2 female: aged 65+) with experience of using ARMED ("ARMED users"). One was recruited from a TOC site, two from non-TOC sites, and one via HAS technology, as someone with several years' involvement

with HAS and extensive experience of using ARMED. All were interviewed individually, with interviews lasting between 25 and 48 minutes (mean 36 minutes).

Of the 22 staff who took part, eight were male and 14 female, and they comprised staff leading services or TOC projects, as well as staff implementing ARMED with service users on a day-to-day basis. All had current or recent (within the past year) experience of ARMED. Ten were recruited from the five TOC sites (Aberdeen HSCP, Argyll & Bute HSCP, Dumfries & Galloway HSCP, Fife HSCP, West Dumbarton HSCP) and 12 from other services using/having used ARMED (East Renfrewshire HSCP, Inverclyde HSCP, Glasgow HSCP, and a Care Home based in Dumfries & Galloway). Activity at several TOC sites was impacted by COVID-19, with projects delayed or halted due to reprioritisation of staffing and services; therefore there was more limited experience of ARMED than had originally been planned for this evaluation. Staff were interviewed either individually (n=11) or in groups of two to three (n=11 participants, 5 interviews), with interviews lasting 21 to 86 minutes (mean 43 minutes). A summary of each site, including their intended and actual (at the time of interview) use of ARMED is provided in Table 2. Throughout the report, illustrative quotes from ARMED users are identified with U and staff with S.

The findings from the four service users are presented first, followed by the staff findings, and finally a synthesis of the key learning and implications from both groups is presented at the end of this section.

II a) Findings: ARMED users

Thematic analysis of the data from the four users of ARMED generated numerous categories and classes of data which, through the process of iterative mapping and interpretation, were organised into six key themes: i) Understanding of ARMED; ii) Motivations for using ARMED; iii) Perceptions of ARMED; iv) Perceived value of ARMED; v) ARMED personnel & support and vi) Suggestions for enhancing ARMED. Each theme is discussed below.

i) Understanding of ARMED

Participants presented a mixed understanding of the purpose of ARMED. Some demonstrated a general understanding of its role in monitoring and prediction, with one participant (U04) having a detailed understanding of the data:

> *"It is a means of collecting physiological and other data which…may, if I deteriorate, monitor me in this way so somebody can step in"* [U04, male]

However, this same participant also described uncertainty over how their data was processed:

Table 2: Summary of sites included in qualitative evaluation

Site description Client group/s TOC/Non-TOC ARMED or ARMED-in-a-box	Intended Use/ Motivation for using	Actual Use
i) Telecare ii) Supported accommodation Non-TOC N/A	Reduce costs Non-intrusive client monitoring & support Interested in impact on younger adults with Learning Disability	Did not get past dialogue stage of negotiations
i) Care at home reablement service users ii) Supported accommodation Non-TOC ARMED-in-a box	Reduce footfall in client's homes (COVID-19 related) Client ownership of health and wellbeing	Purchased: 40 Using at time of interview:17 Implementation affected by technical issues (charging devices) and staff time Focus on assessing whether right for setting and not on interpretation of data
i)Community reablement (own home and supported accommodation) Non-TOC ARMED	Encourage mobility and increase activity Improve support for service users Falls prevention	Purchased:50 Using at time of interview:26 Implementation affected by technical difficulties & staff time Scales not used as felt to be too intrusive
i)Community setting (own home) TOC ARMED	Monitor activity and compliance with prescribed exercises Client ownership of health and wellbeing Falls prevention	Site used 3 ARMED devices Implementation affected by technical difficulties, staff time & COVID-19 pressures Data generated in the time frame not deemed reliable to predict risk Project restarted but abandoned after one month
i)Supported accommodation TOC ARMED	Client ownership of health and wellbeing Gauge resident's reaction to technology	Purchased:10 Used:10 Implementation affected by technical difficulties & staff time Use of ARMED encouraged social interaction between tenants

Table 2 continued		
Site	**Intended use**	**Actual use**
i) Community reablement (own home) TOC ARMED	Promote activity in older people Gain insight into service users	Number of devices used unclear Original Implementation affected by technical difficulties (charging devices) & staff time Current deployment halted at time of interview due to staff shortages (COVID-19 related)
i)Community (own home and supported accommodation) TOC N/A	Monitor activity levels and increase fitness Falls prevention Delay the need for assistance & personal care	Funding secured but project abandoned due to COVID-19 & staff resources being directed elsewhere At time of interview the site hoped to begin rolling ARMED out later in the year
i)Overnight support for adults with learning disabilities i) Residential care home ii)Responder services TOC ARMED	Client ownership of health and wellbeing Facilitate independent living	Number of devices used unclear Data perceived as useful and perception of falls reduction in elderly clients Implementation affected by technical difficulties and staff time
i)Residential care home non-TOC ARMED	Facilitate care planning Monitor and increase activity levels Falls prevention	Purchased:12 Using at time of interview:9 Data perceived as useful Positive experience with initial setup and using dashboard Scales and grip strength unsuitable for frail client group

Key: TOC=Test of Change

"*I'm not terribly clear about how the data is processed thereafter. I've got one or two worries about the fact that I don't really feel quite clear that it is actually being collected…*" [U04, male]

Another participant had misconceptions around what ARMED could detect, suggesting it could detect heart problems or a stroke:

"*If you were going to have a fall…It would be useful for that…Also, people who have heart problems… or a stroke or something, it would pick up readings*" [U03, female]

ii) Motivation for using ARMED

Participants were motivated primarily by the ability of ARMED to monitor physical activity and predict/prevent falls:

> "*I thought this is great because as someone who has fallen a few times, I think this is really a great idea*" [U01, female]

One participant felt it enhanced their relationship with their healthcare provider:

> "*I got to know the occupational therapist…and she was very good, and she asked me would I like to take part in this…And I said I would…*" [U03, female]

One was motivated primarily due to his interest in being involved in the ARMED project as a whole and the knowledge that he is supporting its development to make it more useful to others in the future, as well as feeling it provided reassurance, particularly to someone living alone:

> "*…collecting this sort of information across a wide spectrum of the relevant demographic may – I stress the word **may** – help us understand the type of deterioration that occurs when you're in your mid 80's and with any luck in the future it will enable us to control these deteriorations, manage rather than control them*" [U04, male]

> "*I…liked the idea of monitoring my health, very reassuring, I live alone*" [U04, male]

iii) Perceptions of using ARMED

This was the richest theme, with a range of aspects discussed by participants. Findings are therefore presented in relation to each of these aspects.

General use of ARMED

Some participants described ARMED as being easy to use, whilst others found it technologically challenging or overly complex.

Set-up was particularly challenging for some participants; whilst their initial impression had been their own participation beyond charging and wearing the Polar device would be minimal, this was not the case in reality and more instructions and support would have been welcomed:

> "*I thought, you know, nothing much can go wrong with this, all I was going to be doing was…charging the mobile and charging the watch… you're going to be wearing this watch, which should only be keeping an eye on you.*" [U01, female]

> "...*insufficient information is provided at the beginning. It was a leaflet, an ARMED leaflet which to me... for the average person taking part... I don't think was detailed enough*." [U02, male]

> "*I think if they want you to engage with it that way, they have to put some instruction for people to use it.*" [U03, female]

Syncing was particularly highlighted in relation to technical issues and the need for information on solving these:

> "*Now, sometimes it would switch on, and the initial problems I had was it wasn't syncing. There was no information on why it wasn't syncing. I was told in the leaflet ...how it would sync, but that wasn't happening*" [U02, male]

> "*Why did two, the watch and the mobile, why they weren't working?... one time I phoned...she [Healthcare professional] would come round... she was trying to work the phone and the watch...*" [U01, female]

Participants also reported concern regarding irregularity of syncing and lack of confidence with syncing:

> "*I don't know what the reason for that is. I can sync my phone early in the morning...I can sync it in the evening...manually. But at other times, if I just do a random, it won't do it. So that's the query I have*" [U02, male]

> "*I wish I had some way to monitor that they really are talking to each other at all times.*" [U04, male]

ARMED components

Participants identified both strengths and limitations of each of the ARMED components (Polar device, phone, charger/charging).

For one participant the Polar device was easy and comfortable to wear:

> "*Oh fine, fine, no bother at all. I mean, I was told I could wear it in the shower as well, but I didn't wear it in the shower, but I wore it at all other times*" [U01, female]

For others the Polar device was reported as causing irritation, cumbersome (especially at night), and not conducive to wearing continuously:

> "*I am supposed to wear it 24/7, even when I'm showering... No. Once a day I want this poor skin that's trapped underneath it to get carefully and thoroughly washed and dried. I have no problem wearing it, but I am not technically following the rules 24/7...*" [U04, male]

> "…when I wear it in bed at night, there's a rubber strap which is not very pliable…we put plaster on it and where you put the needle into the hole, that thing kept catching on my bedclothes. That's the thing that would annoy somebody. The other thing you need to know in physical terms is the back of the watch has actually made my husband's skin go quite red and inflamed. But that's got to be left uncovered so …" [U03, female]

One participant reported satisfaction with the phone when it displayed data but also frustration with the phone not working:

> "I thought that it was really fantastic because when I looked at the mobile there was this big circle and it would give…in percentages, when I'd been walking, when I'd been sitting…and then also, you know, when it was not in use at all." [U01, female]

> "...so Friday it worked, then by the Saturday it wasn't working again. And I telephoned, …I said, we can use mobiles, we can use laptops anywhere in the house …there's …nothing wrong with the reception…. So then ...she said to me just ignore the phone. Which I was very disappointed in." [U01, female]

The phone was also reported as needing to work more intuitively and reliably from the user perspective:

> "… from my point of view, to get the maximum benefit out of it… to be able to quickly get out of a problem…" [U02, male]

Charging was anticipated as being easy by one participant, however it was also described as inconvenient by others, with issues of charging the devices reported:

> "Yes…very easy, and I mean, I thought, you know, nothing much can go wrong with this…" [U01, female]

> "…and the…thing is for older people…such a fuss having the one … to change the lead, that was a nuisance. And a couple of times I thought I can't be doing with this …" [U03, female]

> "And what I did, I checked, first of all, that the phone and the watch were charged…I then got into this, whatever it was, Google Assist mode. Then I thought, can't get out of this, switch off, switch back on again. And I couldn't get it out of it…" [U02, male]

ARMED functions

The various functions of ARMED were also perceived in diverse ways.

Physical activity monitoring

ARMED was reported as useful for both monitoring and increasing physical activity:

> *"…well you're really keeping a watch on…the things that you're doing and what is really benefiting you and then what's not benefiting you because you're actually overstepping it and doing too much."* [U01, female]

> *"…but I've persisted…trying to do as much exercise as I can… And I find it beneficial and hence I find the use of this system beneficial to me personally that I can apply it."* [U02, male]

Falls prevention

One participant perceived ARMED as useful for falls prevention:

> *"…I thought this is great because as someone who has fallen a few times, I think this is really a great idea… there's no point in doing it after closing the door, after the horse has bolted. You need to get people doing this, you know, when they're really going to benefit…"* [U01, female]

Another participant perceived potential for falls prevention but did not feel ARMED currently meets this expectation:

> *"…I'm hoping they are going to develop ways of interpreting that data which helps us to understand what factors are promoting this tendency to fall…perhaps give us warning signs. It might at some time in the future…as the equipment develops. It will only develop through inputs when people like myself wear this"* [U04, male]

Promoting physical wellbeing

Participants reported that ARMED motivated them to undertake physical activity:

> *"I wouldn't be so motivated if I didn't have the phone or the watch."* [U02, male]

One participant reported no encouragement in promoting physical wellbeing, but it did make them consider this more:

> *"Directly, none whatsoever. I've carried on as before as I thought I should do. It makes me think a little bit more about the parameters…"* [Uo4 male]

Preventing deterioration

One participant reported ARMED as valuable for individuals in preventing physical deterioration if data is picked up by the relevant healthcare professional:

> *"… these are clinicians by which the data goes to whose job it is to say…we really think it's time for you to …"* [U04, male]

Self-management

Other participants reflected on the value of ARMED in relation to self-management:

> "*I mean I do have a sort of balance problem and I thought well by the use of this ARMED, I mean it's really going to keep me on my toes…You need to be getting up. You need to be getting out and walking. You need to be doing some exercise etc...*" [U01, female]

Sleep monitoring

Participants reported ARMED as useful for monitoring and self-managing sleep:

> "*…the sleep pattern…was quite useful for me because I've not been sleeping well at night, as you can understand, I found that quite useful to know that I wasn't imagining lying awake for 2 or 3 hours at a time.*" [U03, female]

> "*…In cases of sleep patterns etc. Now, I find that helpful … I'm trying to analyse that myself, as to why I'm maybe not sleeping for one reason or another, and whether its diet related in the sense that, you know, I've not been eating the right things, or your bed or whatever.*" [U02, male]

One participant reported difficulty accessing sleep data and questioned whether others may also experience this:

> "*I had trouble accessing it to really get the benefit. I think I sleep fairly well…as a lot of older people do but I wonder if they' d be able to access that data any better than I can?*" [U04, male]

Data

Participants shared a range of views on data including motivation to access data and that data gathering is valuable for individuals and the older population:

> "*we want data from as wide a demographic as we can get because that way the data becomes most valuable*" [U04, male]

Participants also reported that access to data was limited by technical issues and needs to be more user-friendly, visible and easier to interpret:

> *"…you get into that graph mode, and it's like it freezes again… And it stays in that mode and you can't get out of it…You switch off. And then switch back on again…it comes back into the same mode and you can get out."* [U02, male]

> *"as I 've said I find the way they present the data a bit difficult, sometimes very difficult to access. I don't' have the computer mind of a 16-year-old…show me how to do that"* [U04, male]

> *"I go through and I look to see what my heart rate is, and it's just all graphs."* [U02, male]

> *"The data is presented, more often than not, like a clock face with very subtle changes in shades of blue and at my age blue is pretty hard colour to differentiate slight change in shades. I would love to have it [the data] in a tabulated form"* [U04, male]

One participant was interested in their healthcare professional sharing data but not accessing by themselves, whilst another was not clear how ARMED user and healthcare professional data differed:

> *"…I didn't have to do anything …the therapist…came down with some readings for us…there was nothing surprising to me, but she took the information they had gleaned from it and I thought that was quite interesting…"* [U03, female]

> *"…I think the documentation is trying to be at least moderately accessible to the more intelligent user and to carers. At the same time trying to train people who are using these systems as far as individuals whose job it is to deal with the data …those 2 aims ought to be fairly compatible but I don't think they are compatible. I really would like something with more step by step"* [U04, male]

Alerts

Alerts (inactivity stamps from the Polar device) were reported as useful but did not always work:

> *"Potentially this…tells me time to move, I pay attention to that obviously…"* [U04, male]

> *"…we didn't get that at all. In fact, let me mention, if…the voice had said to me …you should be doing more activity, that would have made me move*!" [U03, female]

"…when it was working you know it could ping me if I'd been sitting down too long…" [U01, female]

"It's supposed to indicate to you, if you are inactive for more than an hour ...there's supposed to be an alarm that goes off... Now, that doesn't seem to be working on my phone... I can't find, in any of the menus, how to activate it…it defeats the object of this if you are very sedentary…" [U02, male]

Alerts to charge devices were suggested as helpful by one participant:

"…the only alerts I got were sometimes the disembodied voice saying things like charge your phone it's getting low. That was helpful so you didn't run out…it was mostly charge your phone or charging the device itself." [U03, female]

Impact of using ARMED

Some participants reported that ARMED encouraged activity, but for one it had not significantly impacted on their health behaviours:

"I can see I can achieve a lot with it, both in an exercise way and monitoring my health…" [U02, male]

"…I don't think it's affecting me one way or the other." [U03, female]

Participants varied in their views of recommending ARMED, one reported having recommended it but others described recommendation of ARMED only with consideration of context or caution:

"…I think it would serve a need for some people…" [U03, female]

"I would recommend it to people who are around about what age I am, but it is really your mobility that comes into this and your balance. I would recommend it to people who are, you know, for when you are starting off any balance problems or then, you know, with any walking problems…" [U01, female]

"I mean, that's a question which, it's hard to answer in the sense that, other people ... Are they non-technical people?" [U02, male]

This was accompanied by the view that ARMED is expensive:

"…it strikes me it's quite expensive technology and the other thing that strikes me is given how strapped the councils are for money just now…" [U03, female]

Likewise, they reported that they would continue to use ARMED themselves *"**If** it worked properly"* [U01, female] or for the purpose of their data being used to help develop the system further [U04, male].

iv) Perceived value of ARMED

Participants presented a range of views on the perceived value of ARMED overall, ranging from being confident in its value for falls prevention and early detection/prevention of deterioration to being unsure of its value:

> *"…I believe if I am being monitored and changes…occurs [sic] they'll be picked up much more easily"* [U04, male]

> *"... I didn't know why I was using it except that it was a trial, and I didn't know whether ... in fact the information, I knew they wanted some information from the watch but not to what extent they wanted that information."* [U03, female]

For one participant, its value lay in facilitating the patient-healthcare provider relationship, through discussion of the data captured by ARMED:

> *"That was helpful…because I was getting feedback from [healthcare professional] …"* [U03, female]

Some felt it was not of value to them directly but could see that it may help other older adults, and it was felt by some that further development of ARMED was required for it to be of full benefit to users:

> *"I don't see the need for it. Somebody like my husband would be appropriate because he has had a stroke... but if different people had that [ARMED] and they were monitoring it they could say well...I think you should see the doctor, change your medication or something – that would be good."* [P03, female]

> *"I'm hoping they are going to develop ways of interpreting that data…It might at some time in the future…That's not an unreasonable expectation as the equipment develops. It will only develop through inputs when people like myself wear this..."* [U04, male]

Indeed, it was suggested by one participant that other commercially available products may currently be favourable to ARMED:

> *"…trying to get into parts of the programme… Some people just won't have the patience to persevere with that… I mean, people have got watches now, small watches and Fitbit and …it tells them their basic functions they need to know or want to do, record their steps and whatever distance walked and all that. Very simplistic things. And they are*

probably adequate, whereas maybe for this system, for the average person, it is maybe a bit too technical" [U02, male]

v) ARMED personnel & support

One of the participants disclosed a close ongoing relationship with ARMED since 2016. The participant described ARMED personnel as friends as well as associates and regarded themselves as being "part of the team". This participant had received support directly from ARMED personnel and regarded both the personnel and the support highly:

"I'm very impressed by the system and by the two individuals I am fortunate to be dealing with. They are very supportive, and I can ask questions" [U04, male]

However, other participants reported receiving varying levels of support, with some describing their frustration with either a lack of direct access to, or lack of ongoing access to technical support for using ARMED:

"I was really so sorry that the system did not work with me and then that I could not talk directly to the person who had set it up" [U01, female]

"…because I can't phone up HAS Technology directly, and say to them, you know, why is the phone doing this?" [U02, male]

vi) Suggestions

Suggestions for enhancing ARMED included being able to hire ARMED:

"…what I would go for is if it was possible to hire one for, let's say for a period of three months" [U01, female]

As well as this, access to technical support, user-friendly instructions and user-friendly data were suggested:

"…a helpline number where you could get a technical answer to your problem" [U02, male]

"I would like to get more accessible, intelligible information… I would like… to have it transcribed into tabular form" [U04, male]

"The user would have to be taken through what exactly it does, how to access it and the other thing is older people forget, you need to provide a little simple guide …a wee simple manual, nothing too complicated" [U03, female]

II b) Findings: Staff

Thematic analysis of the 22 staff interviews also generated numerous categories and classes of data. They were congruent with the six key themes for ARMED users and are presented below. Staff participants (S) are referred to throughout by their unique identifier, with details of their practice setting and whether it was a TOC or non-TOC (NT) site provided.

i) Understanding of ARMED

Only three staff described falls risk prediction or falls prevention as the main purpose of ARMED:

> *"ARMED use wearables and environmental sensors to identify changes in patterns of people's lifestyle and behaviour, to help with self-management, to alert the user themselves but also to highlight to others about the risks that someone may be facing due to a whole range of different variables which means you can…anticipate they're at risk of falls before the event happened"*[S5,Telecare/Supported Accommodation, NT]

> *"I think that the main thing that it was offering was just kind of… it gave them a bit of an indication as to when there may be…their falls risk was maybe increasing and when they were maybe not doing enough activity."* [S9, Community, TOC]

Staff commonly demonstrated an understanding of ARMED for monitoring physical activity and inactivity, sleep patterns, and predicting some risk to health (without specifying the type of risk):

> *"…What we're measuring is movement and sleep pattern and the wristwatch sends data into the phone…then the mobile phone sends it on to a database that the clinician…has access to and can see the individual's records and they can, devise a program from that"* [S4, Reablement, NT]

> *"What it stands for is the sort of risk modelling and that sort of early detection and so basically, they're sort of looking to collect data… you know, early on to kind of predict risk"* [S1, Community, TOC]

Staff less frequently discussed monitoring of heart rate, hydration, and weight gain/loss:

> *"…it's a wearable device that somebody would wear on their wrist, and it works on analytics, so you can monitor peoples sleep patterns, hydration levels, their level of activity, and as a clinician you can obviously see this… and be able to monitor what they're doing out with out with…having eyes on them…"* [S12, Reablement, TOC]

> *"…we know how many steps they've done, or how many hours sleep they've had. Gains weight and stuff like that…hydration levels..."* [S22, Residential Home, NT]

Data was also commonly discussed, both in terms of ARMED collecting data and providing data to the ARMED user and staff via a dashboard:

> *"It…involves the individual using a wearable device that captures information related to that person's activity, non-activity, sleep patterns, restful sleep, non-restful sleep…and that information is uploaded onto a secure platform from which information can be used by the practitioner to support rehab planning, to support different conversations with individuals and help them to see…. any improvements"* [S8, Reablement, NT]

> *"It's reporting people's movements, data. Their pulse rates. And then combining that with the scales, grip strength tests and basic measurements, body measurements. All this information is uploaded either Bluetooth through smartphones or through a laptop, as was our hope, to the cloud where it's analysed using algorithms"* [S13, Community/Supported Accommodation, TOC]

Three participants demonstrated an understanding ARMED's use of AI:

> *"…it would it gather data that would generate an alert and then that artificial intelligence that ARMED has recognises any concerns that it may have about that individual. So, whether that was kind of one to three or low, medium, high and that provided early intervention… it just shows that ARMED can predict a potential future health event. ARMED…sold that to us as something they could do up to 32 days in advance…* [S11, Supported Accommodation, TOC]

> *"So, it basically monitors the user and compares that data against, using I think its machine learning…Compares that person's data against themselves and everybody else in similar circumstances, and then uses that data to identify when somebody moves out with parameters …and then gives us the opportunity to refer that person on for medical or other assessment to then get corrective advice, preventative advice or treatment."* [S10, Supported Accommodation, TOC]

Some staff described the various components of ARMED (e.g., wearable, phone, scales, grip strength measurement) with one describing ARMED-in-a-box. The site where the staff member described using ARMED-in-a-box were using it in direct response to COVID-19 where their aim was to reduce footfall into clients' homes, therefore they were not utilising the scales and grip strength products.

" ...we're running what we would call a small test of change with the ARMED-in-a-box devices, it's a mobile phone and the polar flow [polar ignite] *devices."* [S02, Reablement, NT]

Self-management and intervention planning were discussed in one interview with two participants:

"…that was the main thing …they were hoping they would gain from the project, just the kind of prompts for them to take ownership of their… activity levels and kind of prompting to do a bit more activity than they were maybe doing before." [S09, Community, TOC]

"…to support the occupational therapist to be able to monitor remotely and reduce the number of visits that he had to actually go and see people. With the intention that the data could improve the rehab programs that he was setting for people to do, that was the thinking behind the project." [S08, Reablement, NT]

One participant was somewhat vague and understood ARMED to be "a novel technology that could save lives", whilst one perceived that ARMED employed environmental sensors to monitor users.

ii) Motivation for using ARMED

Staff at most sites highlighted monitoring service user's activity levels and encouraging activity as being a motivator for using ARMED within their settings (see Table 2):

"... coming out of COVID ... to monitor... activities to start building people up again. And... giving the physiotherapists and the falls coordinators...insight into what people have been doing or not doing and where they're sitting on their frailty scales." [S12, Reablement, TOC]

Staff at four of the nine sites reported the falls prevention focus of ARMED as a reason they were keen to use it within their service (table 2):

"So, our main hope obviously, was that the equipment would help to as you say, reduce their falls risk, increased activity levels and kind of be a continuation on from the falls input we'd given them before, so that they could kind of self-manage a bit more so that we were maybe not having to get involved as much." [S09, Community, TOC]

Other motivators for using ARMED included reducing footfall into service user's homes during the COVID-19 pandemic, increasing ownership of health and wellbeing for service users, and facilitating care planning (see Table 2).

iii) Perceptions of using ARMED

In keeping with the ARMED users, this was a rich theme, generating a large volume of knowledge on staff views and experiences of using ARMED. Staff identified several strengths and limitations of ARMED, as well as barriers and facilitators to implementing ARMED in health and care settings which are summarised in this section. A variety of aspects of staff's experience using ARMED were highlighted in the interviews and findings are discussed below in relation to each aspect.

General use of ARMED

Although some staff encountered participants who did not like the ARMED technology, most reported that participants were enthusiastic and enjoyed being part of their ARMED projects:

> "... when we were doing ...the handgrip... they were trying to beat each other and see who was the strongest ... they disclosed that information to each other... it was all fun, actually it was a fun time for them." [S17, Supported Accommodation, TOC]

> "Following the survey we did at the end, I just found that there was a lot of good comments from the clients and positive you know, benefits that they felt from it… it motivated them, and it pushed them to move more. So …I think that was quite positive, they actually enjoyed having it" [S03, Reablement, NT]

However, this was often qualified by technical issues and barriers, reported below.

ARMED components

Some staff reported that the Polar devices were large, unattractive and difficult for older adults to take off and on. Providing a choice of wearable was suggested to overcome this limitation. Using and remembering to charge a second mobile phone (where the older adult already has a smartphone) was also reported as a limitation, as was clients forgetting to carry the phone with them. There were some reported limitations with the scales, which were difficult for people to balance on:

> "I mean we understand that they've got to be like that, but a lot of them don't have balance. It's trying to find a way of getting them to stand on it without anybody else helping them, which is gonna give the false reading…That's probably the main thing we've had an issue with." [S21, Residential Home, NT]

This was a particular issue in the learning disability setting, however ARMED offered a solution to this by providing new scales:

> *"Those scales were difficult for people with learning disabilities to stand on. For somebody that's maybe not got the ability to be stable on their feet. So, they got us new scales…"* [S19, Reablement, NT]

Issues with charging was a recurrent theme. Staff reported that clients found it challenging to remember to charge the phone and watch, that some were confused by the different charging cables, as well as having practical difficulties with attaching them to the devices. Significant staff time was required to remind service users to charge their devices, or to physically check the devices regularly. It was suggested that charts developed at one site were useful to some service users as a reminder, and that alerts being sent by the ARMED system to staff when devices required charging was helpful. One site referred to ARMED *"installing MDM* (Mobile Device Management software] *which…seemed to reduce the amount of issues that people were having in relation to charging and syncing"* [S03, Reablement, NT].

> *"…there were two devices… Both required different charging cables… For service users that was an absolute pain, trying to remember which was which, you know having to unplug it from that and plug in the other one…"* [S08, Reablement, TOC]

> *"So yeah, there was a, a bit of an exclamation mark for us just in terms of the amount of work we had to put into to make it work. It wasn't just something that you give to somebody, and you remind them to charge it and then you get the results back…"* [S10, Supported Accommodation, TOC]

> *"…there was quite a bit of time consumed, having to go every morning and make sure they had charged their bracelet, their phone was charged, and that it was syncing. I would say that was probably… the biggest problem I would say. Just making sure…because a lot of them aren't used to using mobile phones…"* [S17, Supported Accommodation, TOC]

> *"We gave them sheets to complete as well. Just to remind them when to charge, when they had charged it, they could fill it in."* [P17, Supported Accommodation, TOC]

> *"ARMED has now set up that we will get an alert when devices are getting to 10% I think it is…we will get an email at that point."* [S07, Reablement, NT]

Although one staff participant reported no issues with syncing of devices, it was an issue discussed by most participants, said to result in data loss and/or concern over accuracy over the data being generated.

> "*There were no issues I believe with, you know, getting it all up and running and getting it programmed and synced and ready to go…*" [S19, Reablement, NT]

> "*…the guy's phone and polar device was out of charge. So, there's no, even point syncing them because once one's out of charge it doesn't hold the data you know, so there's no…point asking him to check it the next day. You can't even have a quick fix at times because you've to wait on it charging…*" [S14, Reablement, NT]

> "*If the phone ran out of charge, then it lost the sync from the device, which meant data wasn't coming through*" [S08, Reablement, NT]

Some participants perceived that the issue may have been addressed since their experience with ARMED (see discussion on MDM above), and it was noted that ARMED can alert staff when a service user is experiencing issues.

> "*ARMED …have tried to overcome a few things, they have now set up an alert it goes to a dedicated email account if the battery is running low and also in our system it's when you log on it on the dashboard lists the clients whose units haven't sunk, so they are, you know trying to overcome these technical issues…*" [S03, Reablement, NT]

> "*I mean we have had some issues with charging before, not holding charge… he [ARMED employee] will fix it the best he can, he does usually come up with a solution pretty quickly.*" [S21, Residential Home, NT]

ARMED functions

Physical activity monitoring was mostly perceived as beneficial for motivating service users, facilitating service user-staff interaction through discussing physical activity, and facilitating care and intervention planning:

> "*Having the data…has been useful for …clinicians…it's also been really useful way of discussing with the clients because you have…graphs and charts that you can take out and …you can show people …how inactive they are…And really if you can improve productivity, they get stronger mentally and physically, so you are…reducing the falls risk and also can increase their function*" [S04, Reablement, NT]

However, it was noted that there was little or no benefit for service users who were previously physically active, and that there was a trend towards initial increases in physical activity not being maintained:

""*we've got some service users on it from the start…but those service users were quite active when they came on to it initially. I think we probably have seen an increase in the amount of hours they are active during the day…the total activity level, but that's not resulted in us saying you know, we can cut their service back...*" [S07, Reablement, NT]

Staff discussed variable engagement from service users with the physical activity monitoring information and reported that some disliked the physical inactivity alerts (vibration from wristband) and the idea that they were being "watched":

"Some people would feel annoyed. I think there was a comment made about Big Brother watching me…" [S19, Reablement, NT]

Staff could mostly see the potential for ARMED to be useful for identifying deterioration and reducing **falls risk** but conceded that the mostly short duration projects could not provide any evidence of impact on falls rates to date:

"I guess… you know… if it can… you know if it can help prevent falls then it, you know, is value for money. Obviously, we didn't get the chance to, you know to get any data or explore that at all." [S01, Community, TOC]

"Our time scales were rather short… not long enough to really be able to …to track somebody…three months isn't long enough" [S10, Supported Accommodation, TOC]

Some also observed that although in general increased physical activity, particularly to enhance strength and balance, is advocated for falls prevention, that for some clients the more active they are, the more at risk they are of falls occurring.

"…by increasing the physical activity, hopefully it would reduce falls because people would build up strength…" [S12, Reablement, TOC]

"…it's quite difficult. The more active people are the more likely …to fall…" [S10, Supported Accommodation, TOC]

One site (Learning Disability setting) was interested in using **sleep data** to assist with addressing sleep patterns, particularly reducing daytime sleeping to encourage night-time sleep and less "wandering".

"…staff were concerned that the service user was taking naps through the day and was requiring support from weeknight overnight staff. Data …backed up the concerns of staff and as a result her care plan was adapted to include a greater choice of activities throughout the day and [service user] slept better at night without the need for many visits or the wakening of overnight staff" [S18, Overnight Support, TOC]

Apart from this purpose, *sleep monitoring* was not widely discussed by staff participants, although they generally felt it could be useful for some people and circumstances, such as long-term conditions monitoring.

Data was another recurrent theme among staff. Although a few participants felt the detailed data was the best aspect of ARMED, with potential for facilitating remote monitoring and falls prevention, it was more commonly felt to be overly complex to access and interpret.

Participants reported difficulty both accessing and interpreting the data, with some concerns expressed over accuracy:

> *"… we didn't really understand all the different options you could select to view the data in more detail, and I think because obviously we aren't like statisticians or anything like that all the graphs and things didn't really make much sense to us at all…so it definitely could be much easier to understand, much more user friendly."* [S09, Community, TOC]

> *"…interestingly the alert, well, the lack of alerts for that person's data suggested they were fighting fit, and they were really, really raring to go, whereas it was just that one snapshot of the whole person and it didn't really tell you the whole story."* [S10, Supported Accommodation, TOC]

Some reported the need for weekly calls with ARMED to interpret the graphs, which was time-consuming and not sustainable in the longer-term.

Negative experiences were fairly common and typically related to: i) the resource-intensive nature of ARMED; ii) the technical issues encountered (reported above, page35-37), or iii) usability issues for both staff and service users. Examples of these experiences are highlighted below.

Resource-intensive nature: Most staff reported the amount of staff time and resources required to resolve technical issues as a major limitation:

> *"…things not working created a bit of stress …just trying to find the time on top of your busy clinical caseload for phone calls or...to solve issues surrounding tech was quite difficult."* [S01, Community, TOC]

> *"…we got to the stage where we, as a group collectively, I mean we had been meeting week after week, after week and highlighting some of the issues that we had. We had to deploy additional resources, staffing resources to the project because of the technical issues."* [S08, Reablement, NT]

> *"We could see some benefits, but overall, it wasn't an overall success in the first phase, because of some of the usability and technical challenges and resourcing points"* [S3, Reablement, NT]

"There was quite a bit of time consumed, having to go every morning and make sure they had charged their bracelet, there phone was charged, and that it was syncing. I would say that was probably the biggest, not a fault, but the biggest problem I would say." [S17, Supported Accommodation, TOC]

Usability: Half of the participants highlighted usability of ARMED within their client group as an issue:

"…they expected them to be more mobile and more active… I think they thought that we weren't doing enough our part to get the people moving and get them involved in the ARMED..." [S21, Residential Home, NT]

"The product and HAS technology as a company, need to be more inclusive...the product should be available to all, I couldn't say to that tenant you can't participate, you're in a wheelchair... that's not right…" [S11, Supported Accommodation, TOC]

A final barrier encountered by some staff participants was COVID-19, which impacted on staff capacity and prevented use of the scales and grip strength

"So, we deployed… a reduced offering from ARMED what we class as ARMED in a box, so we didn't have the full range of devices that were available to us." [S08, Reablement, NT]

"We had applied for funding to roll it out over our localities which we have now returned because we don't have the clinicians available …we do need that buy in across the HSCP in order for the for the project to work, and we don't have it right now, but we haven't ruled it out altogether." [S12, Reablement, TOC]

The main facilitators to using ARMED were related to the people, the software and the hardware:

People: technical support from HAS Technology, regular visits from staff to users, staff engagement with ARMED projects, peer support between users, and support from managers to staff implementing ARMED were all viewed as useful factors in the facilitation of using ARMED.

"...they [service users] *knew that we were there in the background and that we would always help them. So, they were quite relaxed once we gave them that morning knock to say…'is your phone charged and things"* [S17, Supported Accommodation, TOC]

"I found it [using the dashboard] *hard at first because I never really understood it. And then again, [ARMED tech employee] has come in and*

we've sat down, and he's shown me most of it… it's been brilliant. I understand quite a lot of it now." [S22, Residential Home, NT]

Software: prompts to alert staff that users' phones were running low on battery was perceived as a useful addition to the ARMED service.

> *"…they installed prompts on the phones to remind people that the device was needing charged…I don't know if it automatically generated or if it was somebody from HAS technology, they emailed…the OT to let him know the devices were low in charge, so they were very helpful."* [S08, Reablement, NT]

Hardware: receiving additional charging plugs and alternative watch straps were also reported to facilitate the implementation of ARMED.

iv) Perceived value of ARMED

Most staff participants felt that ARMED had actual or potential value, for staff, service users and services themselves.

The value for *staff* was perceived as facilitating a good staff-service user relationship through discussing the data generated by ARMED, giving staff a better understanding of their clients and their respective needs, and potentially reducing times for reablement and reducing falls and hospital admissions. Staff generally felt they did not yet have sufficient evidence for the latter but could see the potential benefit.

> *"The main thing is I've been able to go out and develop a program with the client based on the data and they've got actually got a hard copy of that. They can actually see their movement throughout the day. That's very useful."* [S04, Reablement, NT]

The value for *services* included modernising services, upskilling staff in TEC, saving staff time, facilitating collaboration with colleagues, and planning staffing requirements for client groups. ARMED was seen by some as potentially useful as part of a suite of technology used to support clients.

> *"…it's [ARMED] part of a suite of technology that will allow us to give a holistic view of an individual as and when required and when you combine that with asset management and monitoring…"* [S10, supported Accommodation, TOC]

The perceived value for *service users* included motivating them to be physically active, providing reassurance, empowering patients to manage their own wellbeing and facilitating self-management behaviours:

"it's come up quite a lot at the weekly project meeting - just almost the engagement, the opportunity for clients to feel engaged and take some personal ownership. So, some sort of self-ownership of their journey as well, so that they are involved…" [S02, Reablement, NT]

A social benefit was reported by some participants, related to group measurement sessions (scales/grip strength measures) and friendly competition between peers around increasing step counts.

"…it had become not just a project but a social thing for some of the tenants. A lot of them chose to have their weights and stuff taken on the scales at their properties but there was a wee group…that used to meet on a Tuesday in the lounge…" [S16, Supported Accommodation, TOC]

A small number of staff discussed reduction of falls risk and hospital admissions for service users. One Learning Disability setting was particularly positive regarding the value for their service users in relation to adapting care plans, helping service users be more active and demonstrating increased independence:

"we're able to focus on improving people's activity levels throughout the day. Help them choose other activities which had been suggested by the health and wellbeing teams… assisting people to sleep better overnight…" [S18, Overnight Support, TOC]

However, the perceived value for service users was countered by some staff noting that a fear of technology or of being monitored prevented engagement from some service users, and that where service users could not perceive the benefit of using ARMED, there was an impact on staff time in terms of encouraging service users to adhere to wearing the watch and charging the devices:

"There's been a lot of resistance…some of the comments …I don't want to wear a device. And just about a fear of technology, I think in terms of charging up devices and things like that. So, I would certainly say that you know, service wise we can see the benefits but not from the service user." [S06, Reablement, NT]

A small number of staff did not perceive any value in using ARMED for their client group, stating that it did not solve any problems for them.

The **economic value** of ARMED was discussed by just over half the staff participants. Most could see a *potential* benefit, often qualified by saying "if" it successfully reduces falls and hospital admissions:

"If it works and it was successful, weighing that up against hospital admissions... If we had that information, we might be able to prevent the hospital admission in the first place so…it's like a set of scales isn't it? like weighing apples and oranges or something?" [P12, Reablement, TOC]

However, staff could either not fully evaluate the economic impact from the small projects conducted to date, or they felt ARMED was currently too labour-intensive and/or too expensive to be of value:

"…I don't think we know whether it stacks up from an economic point of view…the labour rate that has to go into to support it...we would really need to consider that as part of it…it's not just about the actual product purchase cost and the ongoing costs, it's about how much resource do we have to put to that. And that might well be the thing that for us makes it quite a challenge...There are undoubtably benefits to both individuals and to their care and to the professionals who are looking after them. But… the actual resource costs that need to go in to make it work effectively." [S02, Reablement, NT]

Some suggested that ARMED-in-a-box may be a more viable option:

"One comment I can make is that is good to see that they are offering more flexible solutions like ARMED-in a-box, which comes as far as I'm aware at different price points…" [S11, Supported Accommodation, TOC]

v) ARMED personnel and support

HAS technology personnel were generally very highly regarded by staff; they felt a good relationship was formed, that personnel were approachable and eager to solve problems, and the regular meetings and ongoing technical support received was highly valued.

"I wouldn't say anything negative about them at all. They were both responsive, if they couldn't find a solution themselves, the put you in touch with someone who could." [S20, Overnight Support, TOC]

"…we got quite a lot of good virtual support from the HAS Technology. You know how to set up the devices, how to scales and grip strength, you know they were quite enthusiastic about the product." [S01, Community, TOC]

"It was mostly one particular member of staff that we dealt with who couldn't have been more helpful anytime I got in touch, my emails were answered, my phone calls were answered and you know, if you asked for extra support for the clinicians that were maybe struggling, it was given, there was there was no issues at all." [S12, Reablement, TOC]

Less commonly, a lack of support was perceived by some to be due to their project being less well-established, and a lack of response to suggestions due to protectiveness by HAS technology of their IPR.

> *"I think it's great that HAS do so much brilliant work…but their focus a lot of the time seemed to be on the projects that were going well when we were reaching out for them for help…Once we got established that was fine, we could go along and we could manage that, but initially sometimes they were difficult to communicate with I would say."* [S11, Supported Accommodation, TOC]

> *"So, it was still a research and development project rather than necessarily a service and that's where that conflict came with ARMED because we wanted to get it attuned to the way we wanted it to suit our own purposes, but I think ARMED were more concerned about providing a service per se without really developing it because of HAS's commissioner's needs."* [S05, Telecare/Supported Accommodation, NT]

Some staff reported what they perceived to be a "pushy sales pitch" which they disliked, and others reported slow response times to resolving technical issues.

> *"I did feel that it was very heavy on the sales pitch. I'm still unsure, so some of the information that they seem to keep firing out that their initial trials…were so successful and things like that. I still don't really see the data…"* [S13, Community/Supported Accommodation, TOC]

> *"…sometimes asking them to do things… you'd like them to be a bit more responsive."* [S07, Reablement, NT]

vi) Suggestions

Perhaps unsurprisingly, suggestions from staff mostly related to overcoming the technical issues described above and making ARMED less complex for both staff and service users. Suggested improvements are presented in Table 3 in order of frequency.

Table 3: Staff suggestions for enhancing ARMED

Suggestions	Illustrative quotes
Resolve charging and syncing issues **Less reliance on ARMED users for operation** **Making ARMED more intuitive for end users**	*"I think if things could be synced. If they don't have to charge things…things may run a little better…I think the technology isn't what it should have been in the first instance. I don't think it was the completed article…"* [S16, Supported Accommodation, TOC] *"… you've got to take the user out of this as far as you can in terms of the technology."* [S10, Supported Accommodation, TOC]
Simplifying, streamlining or improving hardware especially the wearable device NB It was suggested this could also reduce reliance on staff input to support technical issues	*"…some singular device …it has to have that kind of usability factor…the simpler they can make the technology… what we've got just now, but in a more simplistic way that requires less resources…"* [S02, Reablement, NT]
Resolve technical issues **Ensure ongoing tech support is accessible** **Dedicated support team or a support centre**	*"I think if you've got a support centre, and you've got clinicians who are taking the time to try and use this system and then to go to the support centre and say, actually I can't get in for whatever reason… can somebody contact me"* [S12, Reablement, TOC]
Email alerts to indicate to staff when ARMED user activity requires addressed **Simplifying access to the dashboard and interpretation of data**	*"I think it would be good if we could have had the alerts, you know, to the emails to see you know… that patient's high risk."* [S01, Community, TOC] *"We didn't really understand all the different options you could select to view the data in more detail… we aren't …statisticians … the graphs…didn't really make much sense to us at all… it definitely could be much easier to understand much more user friendly.* [S09,]

Table 3 continued

Suggestions	Illustrative quotes
Improving the hardware and Polar device including comfort and choice of wearables	*"If they could get the scales situation sorted…"* [S22, Residential Home, NT] *"… they are quite chunky devices on some people's wrists, if there were other smaller devices…More of a variety of wearable devices …for certain service users, because I know that has put some people off."* [S07, Reablement, NT]
Demonstrate more inclusivity, understanding of client perspective including considering wider aspects of user wellbeing **More personalised detail** **Willingness to collaborate and modify product to meet service needs** **Introduce product slowly**	*"It… needs to be a more holistic and tailored approach to each individual …it's not like…a one size fits all"* [S11, Supported Accommodation, TOC] *"it's about…putting themselves into that position as the end user… to think about it from that point of view…as somebody who doesn't have technical knowledge who perhaps has some dexterity issues, maybe have some cognitive aspects as well, and to think…how can we make that technical product much more usable from an end user perspective?"* [S02, Reablement, NT] *"Gradually building up understanding of the actual abilities of the clients as well, on the use of the devices as well."* [S03, Reablement, NT]
Develop product to combine with other tech or capturing of health data	*"a GPS tracker…could the ARMED not be used like a tracker as well? …"* [S14, Reablement, NT] *"…a robust way of managing people taking their own medication…If things like that could be added to it, that would be very useful…"* [S13, community/Supported Accommodation, TOC] *"I would see that would sit lovely with a lifestyle monitoring more package around it…"* [S19, Reablement, NT] *"…trying to tie that into being a community alarm…so combining that. Make it an all-in-one unit, and not just measuring the data but being able to raise an alarm and give your location would help."* [S13, Community/Supported Accommodation, TOC]

Table 3 continued

Suggestions	Illustrative quotes
Promote product more widely amongst health professionals and general community **Sharing positive accounts of deployment**	"…*better awareness for healthcare professionals so that we know what they are …about and what they offered. I think that would be my suggestion certainly*" [S09, Community, TOC] "…*something that we had that we could share …with clinicians…How did they improve it and this is what they've done to make it better*" [S12, Reablement, TOC]
More conducive to residential settings than community	"…*it would work better… in …residential home setting... the falls prevention and monitoring activity there. I'm not so sure if it's just clear cut in the community*" [S01, Community, TOC]
Consider product branding/name	"…*they've got their anagram…I just don't think it suits the client group …we came up with our own name… ARMED …it just doesn't work…*" [S10, Supported Accommodation, TOC]
Emails going to family members	"…*it was the privacy aspect … they don't want it to be a worry, to be a burden so it would be interesting, I think if the emails were going to family members, I think it might make a difference…*" [S19, Reablement, NT]

2.3 Discussion & Conclusions

The interviews generated an in-depth understanding of feasibility and acceptability, and perceived effectiveness and value for money of ARMED.

In relation to feasibility of using ARMED in health and care settings, although there were some positive experiences, the key finding is that ARMED is not considered by staff to be suitable for widespread use for two main reasons: technical issues and staff resource requirements. These are well-documented barriers to healthcare staff engaging with mHealth interventions, along with individual factors (knowledge, attitude, socio-demographic factors); the human environment (patients' and colleagues' attitudes) and other organisational factors (e.g., training, strategic direction) (Gagnon et al, 2015). Individual factors were also evident in our findings; many staff felt they and the ARMED users did not have sufficient knowledge, particularly for interpreting the data. Other strategic factors were also evident in that the more successful sites were those where there appeared to be management and staff buy-in to using ARMED, or a recognised need to engage with and upskill in TEC. Similar barriers have also been reported for adopting telemedicine, with technology-specific issues the top barrier (Kruse et al, 2016). This may change in light of the rapid roll-out and adoption of telemedicine in response to the COVID-19 pandemic, but technical issues, knowledge and skills have also been identified as barriers during COVID-19 (e.g., Elawady et al, 2020). For ARMED to be adopted within Scottish health and care settings, the technical issues would need to be addressed. There will arguably always be some unforeseen technical issues, especially when the technology is new to staff and users. Therefore, providing user-friendly instructions and technical support that staff and ARMED users can access when required is essential.

In relation to acceptability, again there were some positive experiences. ARMED users in the case-study reports and our own interviews were enthusiastic and generally enjoyed being part of ARMED trials. However, the key finding here is that the many technical and usability issues encountered, as well as some reservations about effectiveness, indicate that there are limitations to the acceptability of ARMED at the current time. Common themes were identified by both ARMED users and staff in relation to feasibility and acceptability (Table 4). Aside from the technical issues, there were practical aspects of the Polar device, including comfort and attractiveness, which have been shown to be important considerations for home healthcare technology for older adults (Charness et al, 2016), and particularly important given that ARMED requires the Polar device to be worn for long periods of time. It is acknowledged that health technologies will only be accepted if they are easy to use, serve a clear purpose and fit into the user's daily routine, and that issues such as having to charge devices and fix technical issues are major barriers (Simblett et al, 2019). Measures to

streamline ARMED and make it less complex for users would enhance acceptability.

Table 4: Comparison of key findings Staff & ARMED Users

	Staff	ARMED Users
Limitations	Polar device discomfort & attractiveness	Discomfort of Polar device
	Set-up, charging, syncing issues	Set-up, charging, syncing issues.
	Data access & complexity	Data access & complexity
	Hardware issues (scales)	Lack of technical support
	Staff resource required	
Strengths	Physical activity promotion	Physical activity promotion
	Service user-staff relationship	Sleep monitoring
	Staff collaboration	
	Empowering users	
Potentially useful with further development and/or formal evaluation	Sleep monitoring	
	Falls prevention	Falls prevention
	Frailty prevention	Frailty prevention
	Preventing hospital admission	Alerts

Key: Black text indicates items of agreement, blue text items unique to staff or ARMED users.

In terms of perceived effectiveness, both staff and users viewed ARMED as effective for promoting physical activity and monitoring sleep. However, as one interviewee pointed out, there are many off-the-shelf devices that offer these functions, without the complexity of ARMED. Consumer-based physical activity trackers are known to increase step count, at least in the short-term (Brickwood et al, 2019), and some have demonstrated good estimation of sleep measurement (Lee et al, 2018). However, ARMED is more than just a tracker and feedback tool, its stated function is to use AI to calculate risk scores, facilitating early intervention to prevent events such as falls. Our participants could generally see the potential for ARMED to prevent falls, frailty and hospital admissions, but felt that further development and longer evaluations that could demonstrate the impact on these measures are required.

In conclusion, this mixed-methods evaluation of ARMED has demonstrated barriers and facilitators to the current feasibility, acceptability, and perceived effectiveness of ARMED. As long as the barriers remain, ARMED is unlikely to be widely perceived as good value for money.

3.0: UK Landscape Review

A rapid scoping review informed by JBI methodological guidance was undertaken to locate and undertake a high-level assessment of technologies similar to ARMED (i.e., falls prevention technologies aimed at older adults), and was submitted as the first deliverable for this evaluation (Cooper et al, 2020). A summary of the findings is provided here.

A comprehensive search resulted in the location of 3,255 potential sources. Following removal of 496 duplicates and exclusion of a further 2,572 sources which did not meet the criteria for inclusion (Table 5), we screened 187 full-text sources against the inclusion criteria, resulting in 64 included technologies.

Table 5: Inclusion Criteria for Landscape Review

Criteria	Description
Participants	Adults potentially at risk of falling
Concept	Falls prevention technology Device: AI, apps, sensors, smart home technology Purpose: Falls prevention OR maintenance of function/activity OR health & wellbeing of older adults
Context	Available on the UK market OR marketable OR near to market

The 64 included technologies were rated as high, moderate, or low similarity to ARMED, with a final category of technologies in development. This allowed a comprehensive map of current and emerging technologies to be generated.

3.1 Technologies in development

The review identified 13 technologies in development, including apps, smart insoles, wearables and a health monitoring system. Their purpose included estimating falls risk, falls prevention, early detection or prevention of frailty, and monitoring of mobility. These technologies were at various stages of development and would require monitoring to determine whether they reach market.

3.2 Low similarity to ARMED

Twenty-one technologies of low similarity were identified. These included apps, remote monitoring platforms and one physical activity measurement device. They were aimed at supporting people to exercise, helping healthcare staff to support patients, reducing or preventing frailty, promoting broader lifestyle changes or measuring activity.

3.3 Moderate similarity to ARMED

Twenty-five technologies were of moderate similarity and comprised wearables, sensors, apps and an AI-driven device. Their purpose was patient monitoring, health promotion, physical activity or general health tracking, improving mobility, balance or muscle strength, and falls prevention or risk estimation.

3.4 High similarity to ARMED

Five technologies were identified that could be categorised as having high similarity to ARMED. Of these, Kinesis QTUG (Kinesis Health Solutions Ltd) was the only device to be highly similar (sensors and AI to identify risk of falls in older adults), was available on the UK market, and conformed to the Medical Devices Directive (MDD). Alcove was highly similar (wearables, sensors and AI to support individuals at home), was available on the UK market, but we could not determine whether it conformed to the MDD. The remaining three technologies (Emerald; Nectarine; Owlytics) all used a combination of wearable technology and AI to predict and/or prevent falls, or to monitor health and vital signs. All three did not appear to be on the UK market and their MDD status was unclear at the time of conducting the review. However, Owlytics does have a strategic partnership with Halma, a UK-based "life-saving technology company".[4]

3.5 Conclusion

ARMED, by incorporating continuous monitoring, predictive analytics, personalised alerts and a healthcare professional dashboard, appears to be a relatively novel technology. Only five other technologies were found that were similar to ARMED in what they can offer individuals and services, with only one being both available in the UK and conforming to the MDD.

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[4] https://www.halma.com/news/press-releases/2019/halma-agrees-strategic-partnership-with-owlytics

4.0: ARMED service deployment model review

4.1 Introduction
This section comprises an overview of the service model review undertaken for the ARMED falls prevention technology. The brief (see page 6) included conducting an:

> *Options appraisal to identify if there is an optimum service model based on the current deployments of ARMED. This is intended to:*

> * *Indicate if there is a most-efficient service model for the deployment of ARMED*
> * *Assess current impact and efficiency of the ARMED service in a real-world scenario.*

The service model review follows on from the findings of the Landscape Review (Section 3) and previously submitted Stage 1 business model review (Fulford et al, 2021).

This section describes the approach employed to assess the impact and efficiency of the ARMED service in the settings where it has been trialled or is currently being trialled. Based on the lessons learned from these trials, recommendations are then presented of some adaptations of, and developments to, the ARMED service that might increase its potential for successful deployment in health and care settings.

4.2 Approach
The data used to inform the assessment of the impact and efficiency of the ARMED service were collected by means of the semi-structured interviews with staff and users at sites where the research team were advised trial deployment of the ARMED service was underway. Details of study participants are presented in Section 2 above (pages 25-28).

The purpose of the service deployment aspects of the interviews was to gain insights into user experiences with the ARMED service, identify examples of good practice, and gain understanding of any bottlenecks or problematic aspects of the service deployment process. A range of topics relating to user experience of the ARMED service was covered in the interviews including the introduction of the ARMED service to staff and clients; the service roll-out approach; user familiarisation and orientation with the service; staff training; access to after-sales support from HAS Technology; fault reporting processes; and data collection and reporting.

Our plan for analysing and reporting the interview data was to identify the ARMED deployment pathways followed at each site, from initial awareness of the service, through to the introduction of the service at the site, and then to the incorporation of the data reporting elements of ARMED into working practices. Essentially, this would allow us to frame our analysis around the innovation-decision process proposed by Rogers, tracing the stages of *knowledge*, *persuasion*, *decision*, *implementation* and *confirmation* at each site (Rogers 2003:170), summarised in Figure 4 and Table 6 below.
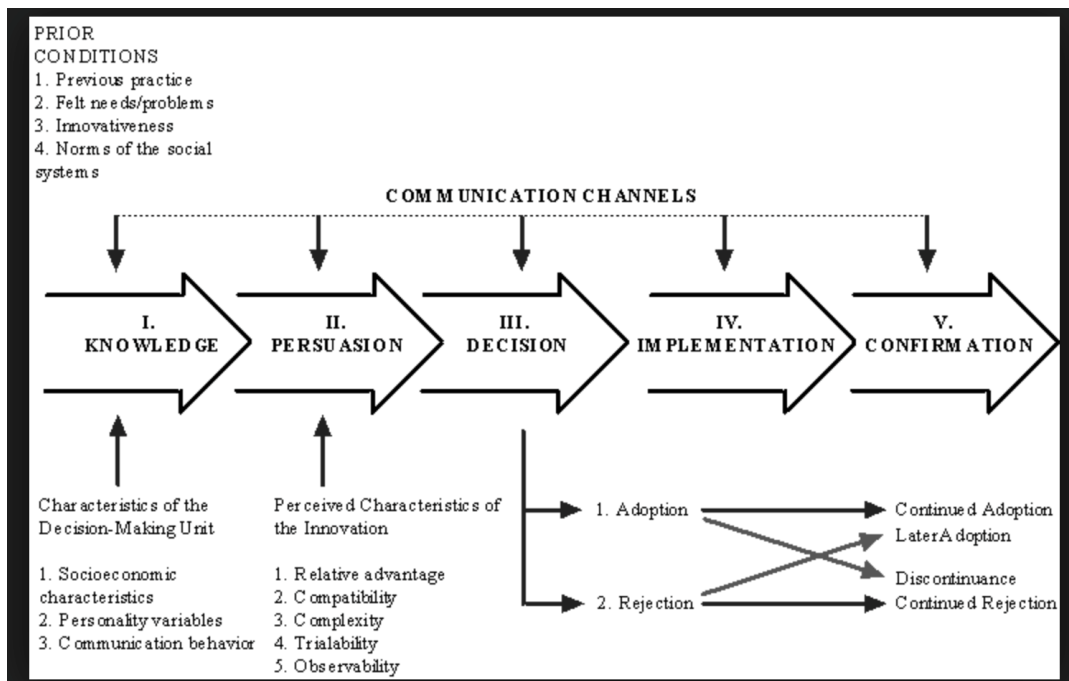

Figure 4: The innovation-decision process (from Rogers 2003)

Table 6: The innovation-decision process (from Rogers 2003)

Stage	Details
Knowledge	This stage commences when an individual (or other decision-making unit) is exposed to an innovation's existence and gains an understanding of how it functions.
Persuasion	At the persuasion stage, the individual forms a favourable or unfavourable attitude towards the innovation. Information about the innovation is sought. Perceived attributes of the innovation are considered, including its relative advantage, compatibility, complexity, trialability and observability.
Decision	This stage takes place when an individual (or other decision-making unit) engages in activities that lead to a choice to adopt or reject an innovation. Adoption is a decision to make full use of an innovation as the best course of action available. Rejection is a decision not to adopt an innovation.
Implementation	This stage occurs when an innovation is put to use. Until the implementation stage, the innovation-decision process has been a strictly mental exercise of thinking and deciding. Implementation involves overt behaviour change as the new idea is actually put into practice.
Confirmation	At the confirmation stage, the individual (or other-decision-making unit) seeks reinforcement for the innovation decision already made and may reverse this decision if exposed to conflicting messages about the innovation.

4.3 Findings

In this section, we present the findings of our interviews at each of the sites. We provide summaries of how the ARMED service has been trialled, or is being trialled at each site, and note the lessons learned from those trials. The findings are summarised in Table 7 below.

Table 7: Experience of deploying ARMED

Site number: Setting	How they heard about ARMED	What Attracted them to ARMED	Experience of trialling ARMED	Decision
Site 1: Supported Accommodation	Previous work with HAS Technology	-Falls prevention focus	**Positive** -Relationship with HAS Technology very supportive -Liked the concept of preventative rather than reactive nature of the product, however, didn't get enough data to utilise this **Negative** -Frequent technical issues including issues charging phone and polar watch, charging cables perceived as hard to use, devices not syncing automatically -Polar watch straps not universally suitable -Resource intensive -Process of collecting grip strength and scale data cumbersome and time consuming	Pilot study adopted then **abandoned** due to COVID-19, frequent technical issues with ARMED and costs
Site 2: Telecare service users	Internet search when researching falls prevention	-Non-intrusive monitoring of clients -Peace of mind for family members	**Positive** -Relationship with HAS Technology very supportive **Negative** -Frequent technical issues including service users forgetting to charge phones, devices not syncing automatically	Trial **paused** at time of interview to allow ARMED time to resolve syncing issues
Site 3: Telecare service users and supported accommodation	Made aware of HAS through Small Business Research Initiative process	-Potential to reduce costs of care delivery -Non-intrusive monitoring and support for clients -Particularly keen to explore the benefits	N/A	**Rejected** – did not get past negotiation stage

		ARMED could deliver for younger people with disabilities		
Site 4: Care at home reablement service users and supported accommodation	Approached by HAS Technology regarding trialling ARMED in a Box	-Reduce footfall into client's homes during COVID-19 pandemic -Potential to encourage self-monitoring and greater ownership of health and well-being for clients	**Positive** -Insight into service user activity is beneficial -Service users were engaged and enjoyed self-monitoring -Relationship with HAS Technology very supportive **Negative** -Frequent technical issues including devices not syncing automatically, service user struggled having only one plug for both devices originally however ARMED did provide additional plugs -Resource intensive -Polar watch straps not universally suitable -Service users found the technology too complex	Trial ongoing at time of interviews – **no definitive decision** had been made regarding its adoption beyond the trial phase
Site 5: Community reablement (own home and supported accommodation)	Previous contact with HAS technology through use of another product. HAS technology contacted service to suggest trial of ARMED	-Potential to encourage mobility and increase activity -Falls prevention focus -Improve support for service users	**Positive** –Insight into service user activity is beneficial -Compliments other technology (e.g. community alarm) well **Negative** -Resource intensive -Users found polar watch uncomfortable -Some users didn't like being monitored -Frequent technical issues including devices not syncing automatically and users having difficulties with charging and cables -Data too complicated for staff	Trial ongoing at time of interviews– **no definitive decision** had been made regarding its adoption beyond the trial phase. However, site highlighted that with the right resourcing and support it could have potential beyond the evaluation phase.
Site 6: Community setting (own home)	ARMED project was passed on from other service in the	-Monitor activity to see if service users are being compliant with exercises	**Positive** -When working watch prompted service users to be more active -Relationship with HAS Technology very supportive	**Adopted then abandoned** after one-month trial due to funding running out. Site uncertain that ARMED is suitable for the current

participants recruited from strength and balance classes	area. Had not heard of ARMED/HAS Technology prior to this.	- Potential to encourage self-monitoring and greater ownership of health and well-being for clients -Falls prevention focus	**Negative** -Resource intensive -Data too complicated for staff -Frequent technical issues including devices not syncing automatically and not having enough chargers, service users forgetting to charge their phones leading to data being lost -Service users found the technology too complex	older population due to technical understanding.
Site 7: Supported accommodation	Project manager had heard of ARMED in previous role. Project team was pulled together after ARMED had been selected as the product to be used in the TOC.	-Potential to encourage the tenants to be more aware of their own physical circumstances as compared to how they feel about themselves - Gauge residents' reaction to technology	**Positive** - increased familiarity and checking wellbeing with tenants through visiting daily to charge/sync hardware - encouraged more social interaction between the tenants in supported accommodation complex **Negative** -Resource intensive -Perception that AMRED was not an inclusive product - ARMED sold as ready to go product therefore initial challenges not predicted or prepared for -Frequent technical issues including devices not syncing automatically and tenants forgetting to charge their phones -Service users found the technology too complex	Initial 3-month project ended in March 2019. Site secured funding for phase 2 which intended to assess if product can be used more widely. This has been delayed due to COVID-19 but plans to be rolled out later this year. **Potential for adoption** of product acknowledged in terms of the wider context of technology supported care from both user and staff perspective
Site 8: Community reablement (own home)	Through a colleague (Falls Coordinator) who had been at a presentation form ARMED and instigated the initial pilot trial	- Promote activity in older people -Give practitioners more insight into service users by accessing data	**Positive** -HAS Technology team supportive and responsive to project managers -ARMED encouraged fun/intergenerational competition with family members who had similar activity trackers **Negative** -Staff members rolling it out struggled to access technological support from HAS Technology -Resource intensive -Polar watches not universally suitable	**Abandoned** largely due to COVID-19. The site had applied for funding to roll it out after the pilot trial was complete, but they returned the funding as they don't have the staff available currently (due to the pandemic). However, the site has not ruled out trialling ARMED again in the future.

			-Dashboard confusing and time-consuming for staff to use -Users sometimes reluctant to wear the device -Frequent technical issues including devices not syncing automatically and connectivity issues (not all users had Wi-Fi)	
Site 9: Community (own home) and supported accommodation)	Presentation from ARMED	-Monitor service users activity levels -Increase fitness and reduce falls -Delay the need for assistance and personal care	N/A	Funding secured but project abandoned due to COVID-19 and staff resources being directed elsewhere. At time of interview the site **hoped to begin rolling ARMED** out later this year.
Site 10: Overnight support for adults with learning disabilities, older adults in residential settings and older adults accessing a responder service	Successful application for ARMED project was made before the staff interviewed were brought on board	-Encourage service users to self-manage their own health and wellbeing -Potential to enable service users to live independently as long as possible	**Positive** -Relationship with HAS Technology very supportive -Helped to focus services -Useful for developing care plans -Facilitated conversations with families about client's care -Perceived reduction in falls in elderly client group -Evidence provided by ARMED data was useful to service -Had a positive impact on service users' views of themselves **Negative** -Resource intensive -Dashboard and data too complicated for staff -Scales and grip strength not suitable for client group with learning disabilities -Some service users with learning disabilities didn't like wearing the watch/didn't like the feeling on their skin	**Adopt** – site has been using ARMED since January 2018. Have extended funding and rolled it out to second group of adults with learning difficulties. The site has also rolled it out to older adults at risk of falls and to a residential care home Keen to keep using it in their setting with slightly different focus: using it at an earlier stage with physio's and OT's rather than reablement

			-Frequent technical issues including having only one plug with multiple cables which caused confusion for some service users	
Site 11: **Residential home**	Contacted by HAS employee in relation to running a pilot scheme of ARMED in their setting	-Reducing falls -Care planning -Increasing/ monitoring activity	**Positive** -Relationship with HAS Technology very supportive -Initial issues with syncing and charging have been resolved -Useful for developing care plans -Initial set up very easy -Positive experience using the dashboard (staff provided with good training) **Negative** -ARMED staff didn't always understand service users' needs or abilities -Scales and grip strength not suitable for their client group, service users could not balance on scales -Service users with dementia didn't understand why they were using ARMED and struggled to engage	**Adopt** - site has been using ARMED for one year and have shown data to their head office with the hope that their site will adopt ARMED

4.4 Discussion and recommendations

The trials of the ARMED service we have reviewed have indicated that the innovation-decision process started positively at each trial site. Interview participants noted that they see the attraction and potential benefits of adopting the ARMED service and were particularly interested in its focus on falls prevention rather than simply being a reactive falls detection service.

As the trials got underway, each site indicated that they had experienced difficulties with various aspects of the ARMED service. These related principally to technical challenges of using the wearable devices, charging the phones, and syncing the devices to ensure consistent data upload for analysis and reporting. In terms of the Rogers innovation-decision process (Rogers 2003), these challenges occurred at the persuasion stage, and concerned the perceived characteristics of compatibility and complexity. Based on their experiences of trialling the ARMED service, the interviewees essentially questioned whether it was compatible with their individual health and care contexts and raised concerns about the complexity of the hardware and software for their specific clients and staff users. Beyond the technical difficulties, concerns were also raised about the business aspect of the ARMED service, notably the pricing model for the ARMED service, particularly in relation to the ongoing costs, rather than the initial upfront investment. In addition, for one site at least, there were concerns about lack of flexibility on the part of HAS Technology to support the customisation of ARMED to their specific care context (young people with learning disabilities). Each of these concerns led to the sites querying the resource implications of deploying the ARMED service, and thus questioning whether it would deliver any relative advantage over existing services and systems.

Given the challenges each of the sites had faced during their trials of the ARMED service, to date only two sites have made the decision to adopt the ARMED service, and indeed three out of the eleven sites have actively decided to reject the ARMED service and abandon any further trials (see table 7).

In light of the experiences during the trials at each of the eleven sites we have reviewed, we make the following recommendations for adaptation of the current ARMED offering:

- Explore ways to simplify the technology aspects of the ARMED service to reduce the current challenges of charging and syncing multiple devices, and particularly to reduce the burden of staff resourcing for deploying ARMED with clients who are unfamiliar with wearable technology and smartphones;

- Explore ways to convert the manual process of uploading grip strength measures to an automated process to reduce workload and decrease risk of errors in data entry;

- Re-visit the pricing model to ensure ongoing costs of using the ARMED service are not prohibitive.

Whilst the above recommendations do not represent an optimal service model, it seems likely that addressing them they would go some way to alleviating the current challenges of deploying ARMED and increase the potential for ARMED to be adopted beyond an initial small-scale trial stage.

4.5 Conclusions
In this section, we have reviewed the ARMED trials that have been underway to date. Findings have shown that the trials largely faltered, and in some cases, stalled. The challenges encountered with introducing the ARMED service into the health and care settings under review have led to abandonment of the trials or to decisions not to pursue further adoption of the service. In the light of the user experiences during the trials, it has not been possible as yet to present an optimal service model for ARMED. However, a set of preliminary recommendations has been presented in the report of aspects of the ARMED service that could usefully be adapted and improved to increase the potential for wider adoption of the service.

5.0: Analysis of current ARMED business model

5.1 Introduction
This section comprises a review of the ARMED business model. The DHI brief for this aspect of the evaluation was to assess the ARMED business model in order to determine the appropriateness and affordability of ARMED for Scotland's health and care sector.

5.2 Approach
The data used to inform the business model review was sourced from internet-based searching and augmented with information contained in the HAS Technology White Paper: *Will Artificial Intelligence set the Standard for Fall detection*, as well as user and staff perspectives drawn from our semi - structured interviews. An interview was also conducted with a Director from HAS

Technology who has responsibility for the ARMED service. This interview was designed to gain insights into each component of the ARMED business model, and to identify plans for development and/or refinement of that model to support the ambition to deliver the ARMED service at scale.

In order to facilitate analysis of the key components of the ARMED business model and to begin to draw comparisons with the business models of ARMED's close competitors, the Osterwalder and Pigneur business model canvas (BMC) concept was utilised as a guiding framework (Osterwalder and Pigneur, 2010).

The BMC is designed to support the description, analysis and design of business models (Osterwalder and Pigneur, 2010). It covers "the four main areas of a business: customers, offer, infrastructure and financial viability" (2010:15) and is divided into nine "building blocks":

- Customer segments
- Value propositions
- Channels (communications, distributions, sales)
- Customer relationships
- Revenue streams
- Key resources
- Key activities
- Key partnerships
- Cost structure.

Figure 5 below provides an illustration of the BMC. The design of the business model sections of the semi-structured interviews were based on a set of guiding questions associated with each building block of the BMC.
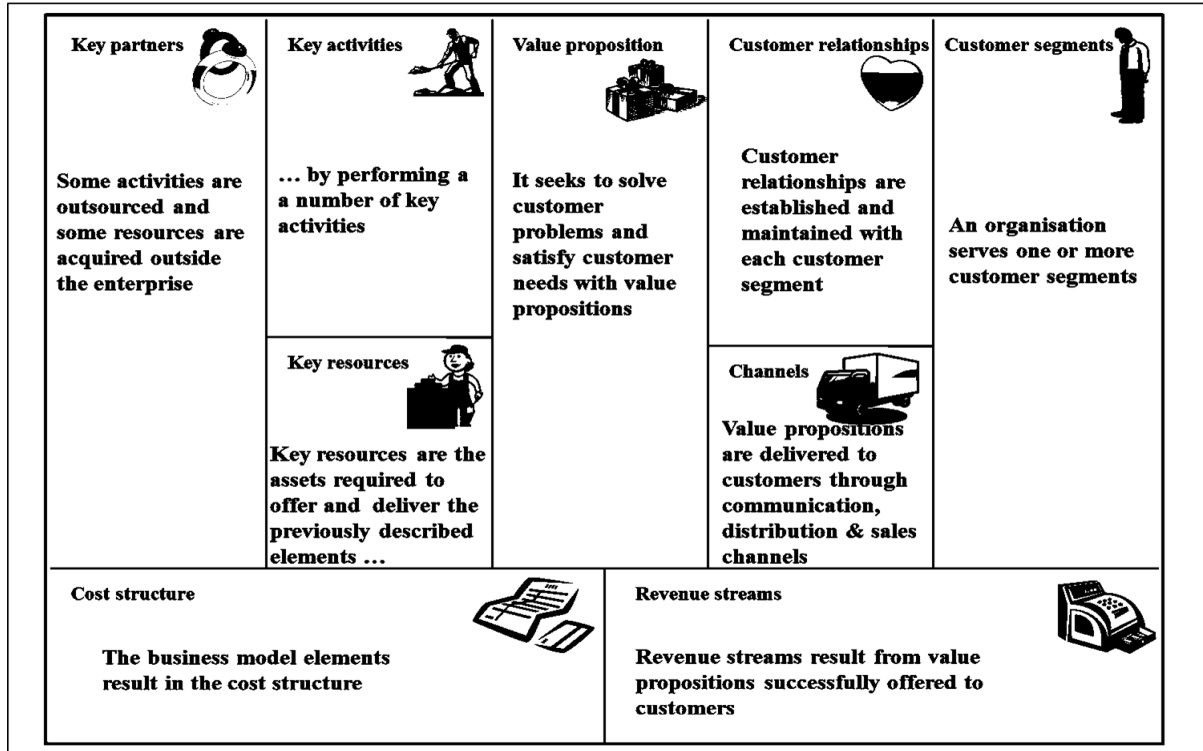
Figure 5: Business Model Canvas (Osterwalder and Pigneur, 2010)

5.3 HAS Technology: company background and development

The HAS Technology Group has evolved from CM Care Management Software (previously CM2000), which was founded in 1999 by Peter Longman and Chris Jackson[5]. The HAS Technology Group has offices in the UK, USA, Australia and New Zealand. A key focus of the group is the provision of technological solutions for health and social care. ARMED is one of HAS Technology's growing portfolio of innovative healthcare solutions. The technologies currently in this portfolio seem to align closely with the Scottish Government's Digital Health and Care Strategy (2018) and the TEC Plan (Scottish Government, 2019), particularly with regard to their contribution to innovation in the areas of self-management of health and wellbeing and remote health monitoring.

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[5] www.hastechnology.com

5.4 ARMED in its market context

Our Landscape Review (Cooper et al, 2020) identified that there are currently few technologies with high similarity to ARMED (5 identified), with Kinesis QTUG and Alcove having the highest similarity (see Figure 6 below). However, the number of technologies with moderate similarity was somewhat higher (25 identified), and 21 were identified with low similarity. In addition, the Landscape Review identified 13 technologies in development. These findings suggest that, although ARMED is not currently competing in a crowded marketplace and is in a phase of early-mover advantage, it is likely to face growing competition as technologies under development are brought to market, and existing technologies are further enhanced to meet user needs.
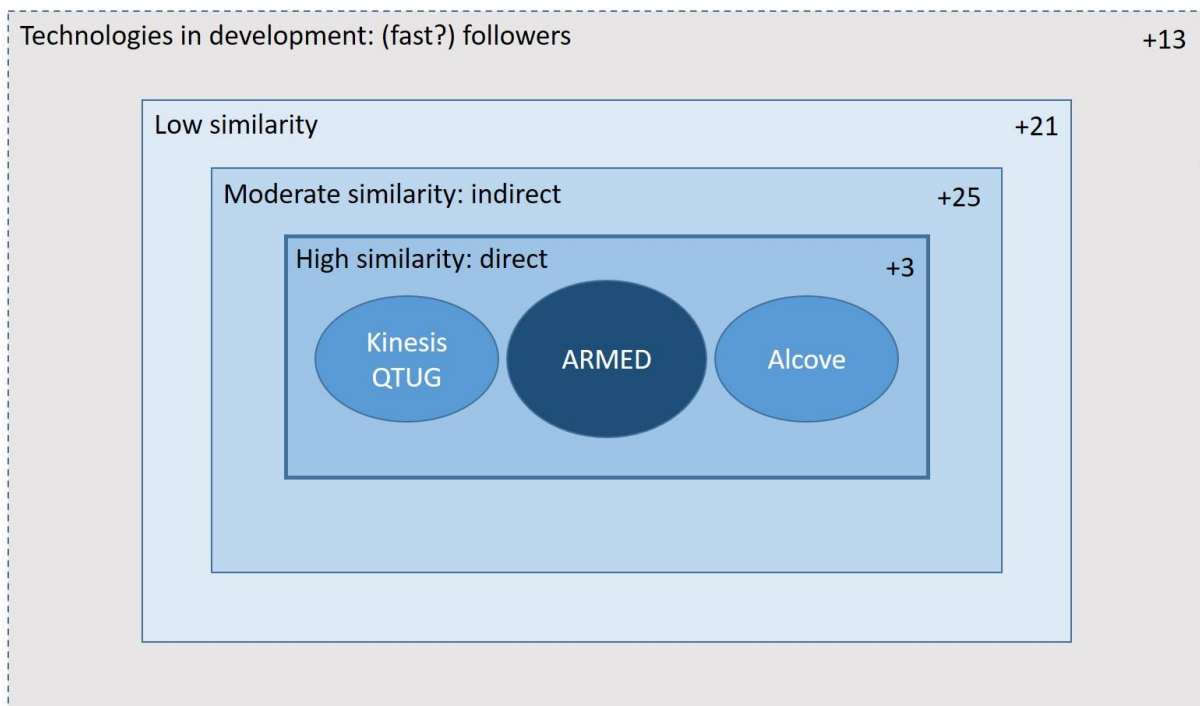

Figure 6: ARMED in its market context

5.5 ARMED: business model

In this section, we consider each building block of the BMC as a framework for discussing findings on the design and efficacy of the ARMED business model.

Customer segments

To date, ARMED has largely been marketed to health and care services, support organisations, housing providers and those who co-ordinate care delivery, particularly among older people. In other words, the model has principally been business-to-business, rather than business-to-consumer.

The interview with HAS Technology provided indications of ambition and scope to grow the market, either through moving to a business-to-consumer model involving selling directly to individual end users, and/or through focusing on a wider range of end users, such as younger adults with learning disabilities or cognitive impairments.

Value proposition

HAS Technology view the core value proposition of ARMED to be its emphasis on falls prevention and supporting self-management. ARMED provides evidence to allow timely interventions to support individuals at risk of falls. It gives healthcare professionals access to information to support activity monitoring, allowing them to pick up on early indications of gradual deterioration that may not be obvious, until it is too late, to family and carers in everyday contact with an individual. Healthcare professionals can be quickly alerted to potential issues, giving a more comprehensive insight into the health and wellbeing of the patient or client. This in turn can support better decision making and allow individuals to stay living independently for longer.

From the staff and user interviews, it was clear that this emphasis on falls prevention was a particularly attractive proposition, and it was recognised by the interviewees that a service such as ARMED could lead to a reduction in falls, and in turn, a significant cost saving for health and care services (reducing, for example, the need for overnight hospital stays).

As well as recognising the potential for falls reduction, staff interviewees highlighted several additional instances where ARMED provided or had the potential to provide value to their service and service users. Staff discussed the use of ARMED to gain a better understanding of their clients' needs, leading to more suitable interventions being deployed. Data from ARMED facilitated conversations between staff and clients, as well as between staff and other healthcare professionals involved in their clients' care e.g., dietitians and health

and wellbeing practitioners. A widely perceived benefit of ARMED was its use in encouraging service users to become more active and take ownership of their activity. Additionally, staff could see a place for ARMED in the shift from reactive to proactive care, with the potential to reduce time for reablement. In terms of benefit to services more widely, staff saw the potential of ARMED in upskilling staff in TEC, modernising services, and planning staffing requirements i.e., prioritising staff time.

Despite technical issues with using ARMED, one user interviewee perceived that ARMED offered value to their own health and well-being in relation to falls prevention. However, another user did not see any value for themselves, but recognised potential value for other users. One user communicated a lack of comprehension as to why they were using ARMED and the relevance of the data. There was a perception that for some users a commercial product (such as an off-the shelf fitness tracker) would track activity adequately and would be more intuitive and less complex to operate. One user discussed enjoying using ARMED and believes that his participation contributes to wider data collection and may enable future development of the product to the benefit of others, but they did not believe the ARMED service was sufficiently developed for this at present.

Given the low levels of actual adoption of ARMED, for many of the interviewees, the value proposition of ARMED for them was still very much at the stage of recognition of its potential, rather than an assessment of the value the service had delivered/was delivering for them.

ARMED comprises a bundle of products and services, notably a wearable Polar device worn by the individual at risk of falls. The Polar device comprises a fitness watch which collects data on vital health signs 24 hours a day. This information is then synced with a smartphone and uploaded to the ARMED database and data analytics service at regular intervals throughout a 24-hour cycle. This is complemented with data gathered through measurements using Tanita body composition scales and strength grip/combination. These measurements are typically undertaken by health and care staff and involve some manual data recording and uploading.

From the staff and user interviews, it became clear that some difficulties have been encountered with the use of the ARMED bundle of hardware and software. Key issues referred to in the interviews included problems with charging the Polar device as care staff found it hard to fit and remove the devices. The older people wearing the devices also found fitting them complex. The charging

system was also perceived to be somewhat complex, perhaps more so than with some other brands of wearable devices. Several sites highlighted that this was, in part, due to only one plug/connector being provided for both the phone and the watch which had separate cables and swapping the cables over was confusing for the service users. One site mentioned in their interview that they purchased extra plugs/connectors to overcome this confusion, whereas another site requested additional plugs from ARMED which they then received. In addition, ensuring the smartphones remained charged had been proving problematic, and this had led to problems with efficient and timely data upload.

One site highlighted that ARMED set up an email alert system to overcome this, whereby an alert was sent to staff when a service user's phone charge dropped to 10% and needed to be charged; this was perceived as a useful solution. Furthermore, the manual measurements involving body composition scales and grip strength were deemed by staff to be rather time consuming and cumbersome, particularly as data entry had to be undertaken manually. As well as being time consuming for staff, the scales were often not suitable for the client group as they were difficult to balance on. It was noted in the interviews that when staff resource is constrained in a care setting, then these additional data recording tasks became an added burden, and it was not always possible to make them a priority. Inevitably, this then led to gaps in the data being collected which reduced the overall efficacy of the falls prevention service. Although a few staff participants felt the detailed data was the best aspect of ARMED, more commonly it was felt to be overly complex to access and interpret.

Channels and customer relationships

With regard to supply of the hardware (Polar device, smartphone, scales etc.) to the end user health and care settings, the approach adopted by HAS Technology has been to procure the devices from the various suppliers and then deliver these as one package to the end user setting. However, HAS indicated that the option does exist for end users to purchase the devices directly from suppliers if they wish. Initially HAS left the staff at each care setting to pair the devices ready for use. More recently, a plug-and-play type approach has been offered as pairing was not always easy for staff or end users to perform successfully.

The approach adopted for introducing the ARMED service to care staff has essentially comprised an informal training and familiarisation model, during which staff are encouraged to trial the devices themselves, wearing the Polar devices, thereby enabling them to see directly the data that can be collected. It was noted in the interview with HAS Technology that follow-up calls to check on

roll-out progress typically occur on a weekly basis at first, and then move to a monthly basis once staff have gained sufficient familiarity with the technology.

Given the ongoing COVID-19 restrictions, HAS Technology has had to confine delivery of post-sales support and training to online platforms, such as via webinars, and via individual phone calls with care staff.

In the staff and user interviews, it was noted that the support provided by HAS Technology has been deemed valuable, and the regular communication, personal approach to follow up and resolution of specific issues or concerns has been particularly appreciated:

> *"I think there's definitely a can-do attitude from them. They've continued to ...haven't just, you know, sold us product then walked away they have continued to actively engage with us and have listened to some of the comments that we've made in terms of where things have gone wrong and have actively tried to…find solutions…"* [S02, Reablement, NT]

The majority of staff echoed this positive experience, however nine out of the 22 staff interviewed shared some negative experiences. One member of staff perceived that established projects were given more support.

> *"Their focus a lot of the time seemed to be on the projects that were going well when we were reaching out for them for help"* [S11, Supported Accommodation, TOC]

Some staff felt that HAS Technology were sometimes inflexible and demonstrated a lack of response to suggestions such as simplifying data presentation and resources. Pushiness of their sales pitch and lack of insight into the needs of their client group were also observed by some participants. Slow responses to communications were also brought up in the interviews as negative aspects of HAS Technology's relationship with some sites.

The relationship-building approach to working with their clients seems to be a key emphasis for HAS Technology, although they acknowledged in our interview with them the potential challenges of delivering such personal levels of support at scale, and according to our interview data are giving thought to the resource implications of growing this aspect of their work. They also noted, however, that their current relational approach allows them to gather useful user feedback to influence product and service development and enhancement.

Cost structure and revenue streams

HAS Technology indicated that the most costly aspect of delivering the ARMED service, alongside the human resource costs, is the fee for the online hosting environment (via Microsoft). The current charging model to end users comprises a fixed price for the hardware combined with a monthly subscription model for the software, charged per head (individual user).

According to HAS Technology, the pricing model has been designed such that one year of usage of the ARMED service approximately equates to the cost of one night in hospital.

Just over half of the staff participants discussed economic value – most could see potential benefit but either could not evaluate the economic value fully from the use of ARMED so far, or felt it to be too labour-intensive for staff for it to be of value. In the interviews, staff could see potential economic value if ARMED successfully reduced rates of falls and hospital admissions. One site suggested that the ARMED-in-a-box model may be more viable. Several barriers to ARMED being cost-effective were identified in the staff interviews. These included the volume of staff resource required to utilise ARMED, the perceived lack of benefit to service users, and the initial expense of purchasing ARMED.

The resource intensity of HAS Technology's current approach to maintaining customer relationships, together with the need of the staff and users in the health and care settings for substantial technical support to operate the ARMED service, could present challenges for HAS to secure a sustainable revenue stream from the ARMED service. This seems to be an aspect of the current business model that may require some further consideration and refinement before HAS are able to offer ARMED at scale.

Key resources, activities and partnerships

Delivery of the ARMED service is dependent on HAS Technology having in place a network of reliable hardware suppliers, as well as a robust data hosting environment. To date, HAS Technology has successfully achieved this through fostering close working relationships with each organisation in their supply chain.

From the staff and user perspectives, it was noted in the interviews that devices with a long service life and reliable mobile networks were key to the effective adoption of the ARMED service.

As indicated earlier HAS Technology is considering exploring the use of wearable device brands other than Polar products. This would increase their range of

supplier partnerships and increase the flexibility of the ARMED offering to customers.

HAS Technology have to date provided in-person after sales service to support staff in each care setting to assist with the set-up of the ARMED service. This has included informal training and support with device charging, syncing, data interpretation, and troubleshooting. These activities are resource intensive, and consideration will need to be given to how this level of customer support can be achieved and maintained should wider adoption of the ARMED service occur.

In addition to customer support provided to staff, service users shared their experiences of support from HAS Technology in the interviews. One user reported being pleased with the initial remote support from HAS Technology when she experienced technical issues, however she was frustrated with the lack of ongoing support. This was echoed by another service user who commented on the lack of direct access to technical support for service users; he suggested that more support from HAS Technology would reduce frustrations and ensure users were able to fully and timeously utilise the product. A third user, who has a close relationship with HAS Technology, was impressed with the personnel whom he contacts regularly, and he appreciates being regarded as one of the ARMED team which makes him feel valued as a service user. The same user suggested that step-by-step guidance on using ARMED would be useful:

"Well, yes, a helpline number where you could get a technical answer to your problem. See, that would have saved me a lot of time in the last three weeks out of the six weeks I've had the phone and getting maximum use out of it."[U02, male]

The design and development of ARMED has been achieved through the establishment of some close partnerships, such as with Edinburgh Napier University and with a number of end user settings such as supported accommodation organisations and care homes. HAS Technology very much views these partnerships as being central to their ongoing product and service innovation. User feedback is greatly encouraged.

Many sites reported that HAS Technology responded to feedback well:

"So, I mean, anybody that takes on feedback and makes the changes. It's got to be good; you know?" [S18, Overnight Support, TOC] talking about HAS Technology.

In contrast, three sites reported that HAS Technology were not always responsive to their suggestions.

"…*they [HAS Technology] weren't prepared to listen to us as a customer and I think that's where our relationship broke down...our brief …was quite clear so I don't think we were being disingenuous by saying can you do x, y and z. This was always a development and innovation project not a service contract.*" [S05, Telecare/Supported Accommodation, NT]

Encouraging and responding to user feedback on product and service challenges and suggestions for enhancement could arguably form a useful part of the ARMED value proposition and help HAS Technology to refine their service to meet user requirements.

5.6 Summary

The emphasis of the ARMED service on falls prevention was perceived by staff and the users we consulted as an attractive value proposition. Participants could see the potential of the ARMED service to deliver benefits of cost savings, time savings and increase clients' opportunities for retaining independence and supporting self-management. Given the low levels of actual adoption of the service to date, this value proposition, however, has yet to be fully and robustly tested in health and care settings.

The technical difficulties (hardware, software and data management) of introducing and implementing ARMED which were encountered by many of the sites currently seems to be a key barrier to realising the value of the ARMED service.

The current focus of ARMED is on older people prone to falls. However, there seems to be potential to expand the offering to other customer segments, such as younger people with learning disabilities, and ARMED has been used with some success for sleep monitoring with this client group in one of the included sites. To achieve this, some careful thought will need to be given to the precise value proposition for each customer segment to ensure that the service can be appropriately promoted to each one. Careful thought will also need to be given to ARMED-in-a-box. We did not have sufficient data on ARMED-in-a-box to evaluate it separately. However, care will need to be taken by HAS technology to avoid undermining their original value proposition by introducing this service that does not require the biometric scales and handgrip assessments. Alternatively, they will need to adopt a separation strategy with a separate value proposition and business model for each product (ARMED and ARMED-in-a-box).

HAS Technology's current business model is currently resource intensive, particularly with regard to providing after-sales support to each health and care setting. This aspect of the model is likely to need to be re-designed if delivery is

to be scaled-up in order for HAS to be able to meet the set-up and ongoing technical requirements of users.

Although HAS Technology perceives their pricing model to be straightforward, the experience at some of the sites was that it was not necessarily transparent, and this was deterring them from adopting ARMED. Again, this aspect of the business model would benefit from some re-design to ensure full transparency enabling each health and care setting to budget for the service, and to be able to track return on their investment.

The ARMED service currently relies on some key partnerships with a small number of hardware, software and data management suppliers/providers. There is a narrow focus on partnerships. Given some of the technical difficulties encountered at many of the sites with regard to introducing and implementing ARMED, it would seem prudent for HAS to revisit this aspect of the business model through exploration of other device suppliers and data service providers. In particular, investigation of wearable devices would be useful in order to identify those which would alleviate the charging and syncing challenges experienced at many of the sites which participated in the evaluation.

6.0: Summary & Recommendations

6.1 Key findings from the evaluation

ARMED is a novel technology with the potential to address an important and costly health issue (falls), as well as supporting the wider agenda around early intervention and independent living.

We were not able to determine ARMED's impact on falls prevention or to make specific recommendations on its scaleability, largely due to the lack of available data, due to evaluation sites being at an early stage in the adoption decision process. We were able to determine that, in a small sample of users, modest health benefits were suggested for some participants, and that ARMED was generally perceived positively by the users concerned. Both staff and ARMED users viewed ARMED as effective for promoting physical activity, monitoring sleep and facilitating collaboration (staff-to-staff & staff-to-service user). Participants could also generally see the potential for ARMED to prevent falls, frailty and hospital admissions, but felt that further development and longer evaluations are required to fully evaluate the impact of ARMED on these outcomes. We identified several positive examples of the use of ARMED in health

and care settings, but technical and usability issues and resource requirements suggest that ARMED is not currently suitable for widespread adoption in these settings. The highly staff-intensive nature of ARMED as implemented by the sites included in this evaluation may render it prohibitive for many services.

The service deployment model review identified from the perspective of Rogers innovation-decision process (Rogers 2003), that ARMED currently faces challenges at the persuasion stage, due to issues with compatibility and complexity. The interview findings can also be viewed through the lens of the NASSS (non-adoption, abandonment, scale-up, spread, sustainability) framework (Greenhalgh et al, 2017). We mapped our findings to the first five NASSS domains (condition/illness; technology; value proposition; adopter system; organisation). It was not appropriate to evaluate the remaining two domains (wider context; embedding and adaptation over time). Viewed in this way, the findings are congruent with Rogers' innovation-decision process, i.e., there are complicated and complex issues to be resolved before ARMED can be considered for adoption, borne out by the number of sites who abandoned use.

We were not able to recommend an optimal service model for ARMED, in light of the user experiences and stage of adoption at the included sites. Rather, we have made a set of preliminary recommendations for increasing the potential for wider adoption of the ARMED service.

Participants viewed ARMED's emphasis on falls prevention as an attractive value proposition, with potential to deliver cost and time savings and to support self-management and the maintenance of independence. However, the technical difficulties encountered by many of the sites in this evaluation seem to be a key barrier to realising the value of the ARMED service.

We have identified several aspects of the business model that HAS technology could review in order to move towards scale-up, including refining the value proposition for specific customer segments; considering widening the partnership base to include other hardware providers (e.g., trackers/watches); considering the value proposition and business model for ARMED and ARMED-in-a-box, and redesigning after-sales support and the pricing model.

6.2 Recommendations

For Policy

The findings of this evaluation suggest that the ARMED service has potential, but is not currently ready for adoption at scale within the Scottish digital health and care context. Recommendations are made below for further development of the

ARMED service and to increase readiness of services to adopt ARMED, or other similar types of technologies.

Learning generated by conducting this evaluation has informed the recommendation that when pursuing adoption at scale of remote health monitoring technologies such as ARMED, the following should be ensured:

Recommendation 1

The technology has been thoroughly and rigorously tested (and refined where appropriate) with the intended users and in the intended service settings and contexts. We recommend that a checklist is developed for this purpose.

Recommendation 2

Independent evaluation of readiness for adoption should be conducted. We recommend that a standardised assessment is developed specifically for the Scottish Digital Health & Care context.

Recommendation 3

Robust and standardised evaluation designs should be used at each test site to ensure consistency of data for analysis.

For HAS Technology/ARMED

Recommendation 1

Ways of simplifying the technology aspects of ARMED should be explored to reduce the current challenges of charging and syncing multiple devices, and particularly to reduce the burden on staff and resourcing for deploying ARMED with clients who are unfamiliar with the technology and /or who struggle to gain familiarity and engage with it. This would support adherence and confidence in the technology.

Recommendation 2

Clearer and more user-friendly technical support and guidance on set-up and ongoing use should be provided to all individuals and staff using ARMED, including hardware, software and data management. This guidance and support need to be accessible, timely and appropriate for all users (individuals and staff). Furthermore, thought needs to be given to how this could be provided at scale, and in formats that are most appropriate for each health and care setting. Options that could be explored include a web-based source of information, user manuals/instructions (including video guidance on specific aspects of ARMED set-up and usage), and frequently asked questions on technical issues, with the option of accessing technical support staff where required.

Recommendation 3

Difficulties around accessing and interpreting the data need to be addressed, in order for ARMED users (individuals and staff) to engage in the full functionality of ARMED and for it to be used for its intended purpose i.e., fall prevention.

Recommendation 4

Ways of converting the manual process of uploading grip strength and body composition measures to an automated process should be explored, in order to reduce staff workload and the risk of errors in data entry.

Recommendation 5

The potential should be explored for ARMED to be deployed for a wider range of purposes beyond its initial application for fall prevention. For example, its potential for application among people with learning disabilities living in sheltered accommodation could be further investigated. In pursuing this, care will need to be taken to ensure that the specific value proposition of ARMED for each customer segment is clearly identified and communicated. Likewise, marketing, sales, and after sales processes will need to be appropriately designed for each customer segment

Recommendation 6

Ways of introducing the ARMED technology gradually to users should be explored in order to ensure they can understand its purpose and be comfortable using it, and in order to increase the likelihood of adoption. Examples of effective strategies could be collected from staff and users, and shared as part of the user guidance and support

Recommendation 7

The pricing model should be reviewed to ensure that the ongoing costs of using ARMED are not prohibitive to a service adopting it.

Recommendation 8

A clear and distinct value proposition for ARMED-in-a-box should be identified and articulated, with each element of the business model developed for this offering.

Recommendation 9

Eligibility for funding opportunities, should be explored, such as a Management Knowledge Transfer Partnership (KTP), to help refine and robustly test the ARMED business model and prepare the service for delivery at scale.

For Services

Recommendation 1

Services need to allow sufficient time for familiarisation, training, set-up and implementation of ARMED, in order for staff and service users to understand its intended purpose, to feel comfortable using it and to have confidence in ARMED. This is particularly important for service users and staff who are less familiar with technology.

Recommendation 2

Services need to ensure adequate staff resource is available before attempting to implement ARMED in their setting. A dedicated staff member with a remit to lead on ARMED is advisable.

Recommendation 3

Services need to carefully consider the appropriateness of their client group for ARMED, including their ability to interact with the technology and to use it independently, their willingness to use it and their potential to benefit from ARMED.

Recommendation 4

When considering testing ARMED in a service, consideration needs to be given to appropriate baseline measures (e.g., falls rates) and to routinely gathering data that can be used to evaluate the impact of ARMED.

6.3 Strengths and limitations of the evaluation and recommendations for the future

Strengths

A strength of this evaluation is that it was conducted by an interdisciplinary team with expertise in the fields of falls prevention, older adults, business, and the full range of methods required for this evaluation. The team also included a clinician with first-hand experience of an ARMED TOC project.

All the people who took part in this evaluation were generous with their time, and spoke honestly and freely about their experiences of ARMED; this greatly assisted the evaluation and provided a wealth of data.

We employed a flexible and comprehensive recruitment strategy, and despite the limitations caused by COVID-19, we recruited from all five TOC sites and also from other non-TOC sites.

Limitations

COVID-19 inevitably had an impact on this evaluation. The TOC sites and some of the non-TOC sites had their ARMED projects halted due to the pandemic, which affected availability of data and of people with experience of using ARMED to take part in interviews. On top of this, health and care staff were under pressure and many would not have felt able to take the time out to take part in the evaluation. Our interview sample was smaller than we had aimed for; however, we are confident that we reached data saturation for the staff interviews. It would be beneficial to capture the views of additional ARMED users in future due to the small sample and limited range of experiences. We are also confident that many of the barriers and limitations raised, such as technical issues, charging and syncing issues, and complexity of data, were not directly related to COVID-19.

Not only was the lack of quantitative data a limitation, but the data itself, which lacked standardisation across the TOC sites, lacked baseline measures with which to make comparisons, and lacked detailed costs in relation to staff time to facilitate cost-effectiveness analysis.

Recommendations for future evaluations

We were able to generate evidence on some aspects of ARMED, such as feasibility and acceptability, but not on effectiveness or cost-effectiveness and we are unable to recommend widescale adoption of ARMED at this time. In order to do so further robust evaluation should be undertaken and should include:

- Standardisation of data collection with agreed valid, reliable and logistically feasible measures to facilitate pooling of data from different sites using ARMED.
- The use of valid measures of the constructs of interest (e.g., physical: balance, mobility; psychological: balance confidence, activity avoidance) which are carefully selected and matched with tests that provide assessment of the construct.
- The use of reliable tests that include minimal variation over short periods of time. Attention should also be paid to implementing protocols to maximise reliability (e.g., timing of tests, instructions provided, equipment used, measurement of multiple tests with averages taken) Prior to roll-out of tests, the scientific literature should be reviewed to determine if tests have appropriate reliability with the population of interest, or pilot testing may be considered.
- The use of measures included in scientific literature, in order for comparisons with similar population and technologies to be made.

- Ensuring that testing batteries are logistically feasible, taking into consideration the physical and emotional stress they place on participants, and that staff have capacity to complete testing batteries at regular intervals. This will enhance compliance and minimise drop-out across evaluation sites.
- Collection of baseline measures (e.g., falls rates) and sociodemographic variables of samples before ARMED is implemented.
- Larger and longer evaluations that are designed to evaluate effectiveness and cost-effectiveness e.g., adequately powered randomised controlled trial comparing ARMED with usual care, with collection of pre-intervention, post-intervention and follow-up measures and cost data regarding equipment costs, cost of support from ARMED, and costs of staff time.
- Comprehensive exploration of barriers to adoption at all levels e.g., technical, service-level, supply chain.

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