D3.4 - Advancing the use of visual systems to support older adults managing multiple chronic health conditions

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- Draft (D): describes planned contents and main structure of the different sections. Document is between 0% - 50% completed.
- Intermediate (I): document is approximately between 50% - 100% completed. It is the previous step before it could be released.
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List of abbreviations

AAL Ambient assisted living

ADLs Activity of daily livings

CN Care network

COPD Chronic obstructive pulmonary disease

CVDs Cardiovascular diseases

EU The European Union

FSCQ Future Self-Continuity Questionnaire

HSE The Health Service Executive

MSK Musculoskeletal

NCDs Non-communicable diseases

PD Parkinson’s Disease

PEU Perceived Ease of Use

PU Perceived Usefulness

PwM Persons with multimorbidity

RGB Red Green Blue sensors

RGB-D Red Green Blue-Depth sensors

SMS Self-Management Support

TAM Technology Acceptance Model

TDF Theoretical Domains Framework

Executive summary

The aim of this deliverable is to provide a mid-term evaluation report on the use of camera-based technologies for older adults living at home with multiple chronic health conditions (multimorbidity). The deliverable provides feedback on research outcomes from ESRs 7 and 8 on how the respective ESR PhD topics have advanced knowledge in 3 core areas:

1) The application of visual systems to support self-management activities for people with multimorbidity (ESR 7)

2) The impact of visual systems on changing behaviour to improve disease management processes (ESR 8).

3) The evaluation of strategies most appropriate to address end-users privacy and ethical concerns for camera use within the home (ESR 7 and 8).

Within the deliverable, ESR 7 will focus on the application of visual systems to support self-management activities for people with multimorbidity (see section 2) and ESR 8 will report on the use of behaviour change theory and techniques to improve older adults' acceptance of these visual systems (see section 3). Section 4 will present collectively outcomes from ESR 7 and ESR 8 on the evaluation of strategies most appropriate to address end-users' privacy and ethical concerns for camera use within the home. Please note ESR 9 will not contribute to this deliverable. On agreement with the project officer, the PhD focus of ESR 9 was changed to focus on privacy-aware embodied intelligence for robots in assisted living environments.

Finally, it is important to note this deliverable presents initially findings from research currently in progress, primarily across the first 18 months of the research programmes of ESR 7 and 8. An update to this deliverable will be provided in D3.5 in M50.

1. Introduction

1.1 Population ageing

The world's population is fast ageing. It is estimated that the global share of older adults will increase from approximately 10% in 2022 to 16% in 2050, representing a near doubling in the number of older adults by mid-century (United Nations, 2022). The macroeconomic implications of population ageing cannot be understated, as there will be increasingly fewer individuals of working age to provide for ever-inflating healthcare, pension, and social security costs (Suzman et al., 2015). Furthermore, older adult populations are expected to be over-represented by persons with multimorbidity (PwM) – i.e., individuals with two or more chronic conditions (Marengoni et al., 2011). Due to strong associations between multimorbidity and reduced functional capacity (Palladino et al., 2016), the likely result is reduced quality of life for older adults and significant economic downturn (Marengoni et al., 2011).

1.2 Ageing-in-place

Ageing-in-place is frequently evoked as a panacea to population ageing and the associated expansion of morbidity and multimorbidity. Broadly understood as older adults "being able to remain living in their community as they age […] as opposed to relocating to a care facility or living elsewhere" (Neville et al., 2018), ageing-in-place focuses on decentralising the provision of care for older adults from costly acute or institutional settings to the home environment (Sixsmith & Sixsmith, 2008). This thrust towards ageing-in-place is buttressed on for several reasons. First, there are significant economic savings associated with supporting older adults to live in their original places of residence. Because institutional care can be costly, reserving this care for older adults with more acute care demands such as frailty or dementia and encouraging those with more manageable chronic diseases to self-manage from their own home has the potential to decrease government expenditure (Horner & Boldy, 2008). Second, it is well documented that older adults prefer to continue living at home and remain in their community as they age, as the private home (compared to residential care) is typically seen as conferring more comfort, privacy, security, and comfort (Boldy et al., 2011; Sixsmith & Sixsmith, 2008). Conversely, long-term residential care is one of the most pervasive sources of anxiety, fear, and stress marking later life, and is often seen as a last resort to older adults (El-Bialy et al., 2022; Lee et al., 2013). These rationales account for the immense and ever-increasing policy drive for ageing-in-place.

1.3 Active and assisted living (AAL) technologies

The accumulating pressures of population ageing have renewed policy interest in remedial strategies that feature the use of technology. In particular, active and assisted living (AAL) technologies have been increasingly invoked as a key facilitator to the ageing-in-place agenda (van den Broek et al., 2010). Broadly defined as technologies designed to help older adults lead healthier, better, and safer lives in their preferred living environments (van den Broek et al., 2010), AAL technologies can confer a host of care and support functions for older adults, including but not limited to:

- Monitoring and acting on individuals' environments for increased safety and comfort.
- Monitoring human activity and behaviour for on-demand, acute care provision (e.g., fall detection) and;
- Enacting long-term behavioural analysis and personalised risk assessments for early disease detection, prevention, and management (Blackman et al., 2016; Colantonio et al., 2018; Dasios et al., 2015)

Through both reactive and proactive means of caring for older adults, AAL technologies are thought to augment older adults' quality of life whilst alleviating the costs and burdens otherwise borne by formal primary and secondary care infrastructures (Blackman et al., 2016; Colantonio et al., 2018; van den Broek et al., 2010).

A characteristic feature of AAL technologies is a capacity to support older adults via unobtrusive, ubiquitous, and intelligent, and user-friendly means. The concept of "ambient intelligence" refers to the integration of technologies into people's everyday lives and activities, such that care and support functions can be enacted without explicit human involvement or even awareness (Espinilla et al., 2019). For instance, environmental sensors can acquire information about the surrounding temperature, humidity, air quality, and lighting conditions and take corrective measures to secure more comfortable living environments for older adults (Marques & Pitarma, 2016; Sayuti et al., 2017). In cases where older adults are incapacitated or otherwise unable to seek help, AAL technologies can also detect potential environmental hazards (e.g. gas leaks) and automatically contact the relevant authorities for assistance (Sixsmith, 2006). In such ways, AAL technologies are thought to secure safer and better-quality lives for older adults whilst circumventing the need for extraneous effort from older adults themselves. Importantly, this unobtrusiveness is thought to benefit the acceptability of AAL technologies for older adults (Colantonio et al., 2018).

1.4 Camera-based active and assisted living technologies

Within the ever-expanding corpus of AAL technologies, a new generation of camera-based technologies is notable. Camera-based AAL technologies can be broadly understood as those technologies that leverage on computer vision techniques (i.e., cameras, videos, etc.) to carry out AAL functions (Colantonio et al., 2018; Planinc et al., 2016). Imaging techniques have been described as “the most straightforward and natural way” to acquire information about events, persons, objects, and interactions, and are on this account construed as a prized mode of ambient assistance (Ake-Kob et al., 2021). While camera-based AAL technologies have similar care and support functions compared to conventional, non-visual modes of ambient assistance, a few distinguishing features of the technology are noteworthy. First, the breadth of camera-enabled monitoring surpasses that of conventional, non-visual technologies: a single camera placed in the room can detect and record most activities performed in said room, which would have otherwise required the integration of multiple non-visual sensors (Ake-Kob et al., 2021; Colantonio et al., 2018). Second, ever-increasing advances in the field of computer vision have benefitted more affordable yet high-quality cameras, allowing important behaviour indices and environmental parameters to be captured in rich semantic detail but at modest prices (Ake-Kob et al., 2021; Colantonio et al., 2018). Therefore, camera-based AAL technologies are increasingly invoked as a feasible and practicable means of delivering on the ageing-in-place agenda (Ake-Kob et al., 2021; Colantonio et al., 2018).

Video-based camera systems have been used in many AAL systems and in-patient healthcare setting (hospitals, primary care centres or nursing/care homes) for different reasons like; in-patient safety monitoring of fall risks (Cournan, Fusco-Gessick, & Wright, 2018), video communication (Crosby, Hanchanale, Stanley, & Nwosu, 2021), cognition and behaviour monitoring (Abbe & O'Keeffe, 2020) or vital signs monitoring (Molinaro et al., 2022). These collected video-based data can provide rich feedback for an individual's (managing chronic health conditions) care network (CN) including healthcare professionals to observe, assess and support the individual. Moreover, video-based data has the potential to help healthcare professionals to recall data when needed to assess older adults (Mackenzie & Xiao, 2003) enabling more tailored and optimised care. However, concerns about data accessibility, data privacy and technology acceptance have been raised, so more privacy-aware and acceptable video-based interventions are needed (Arning & Ziefle, 2015; Romanou, 2018).

2. The application of visual systems to support self-management activities for people with multimorbidity

2.1 Research challenge: Living with multiple chronic conditions

Non-communicable diseases (NCDs) are group of chronic diseases, mainly diabetes, cancer, cardiovascular diseases and chronic respiratory diseases, accounting for 70% of the global deaths and share the same modifiable behavioural risk factors of physical inactivity, unhealthy diet, tobacco use and alcohol over consumption (WHO, April 2021). The European Union (EU) is most affected by NCDs, which are contributing to 80% of the disease burden among the EU countries and the foremost cause of the premature deaths (EC, 2021a). Due to the EU's ageing population, the level of multimorbidity (MM) has increased to more than 40% in 15 EU countries between 2004-2017 (Souza et al., 2021), creating pressure on the healthcare systems, increasing health care spending to 20% of Gross Domestic Product (GDP) (EC, 2021b). Therefore, a new model of care with more innovative patient-centred for PwM is needed (EC, 2021b) to improve health outcomes, decrease hospitalisation and unnecessary hospitals visits.

Definition of Multimorbidity

The WHO (2016) defines multimorbidity as the "co-existence of two or more chronic conditions”. This could be in the form of different chronic conditions; including physical (which may affect any of the body organs and systems); mental (which could lead to any mental disorders for instance depression or schizophrenia); or cognitive disorders (that affect the memory, orientation, or logical thinking). Comorbidity has been used interchangeably with multimorbidity to describe the occurrence of more than two chronic conditions. Comorbidity firstly entered the academic literature in 1970 by A.R. Feinstein who defined it as the “distinct additional occurrence of another clinical condition due to an already existed disease” (Feinstein, 1970).

A bibliometric analysis paper scanned the used terminologies to describe the coexistence of more than two chronic conditions and concluded that “*polymorbidity*”, “*polypathology*”, “*pluripathology*”, “*multipathology*” and “*multicondition*” are other terms used to describe multiple chronic health conditions (Almirall & Fortin, 2013). In J. Almirall’s bibliometric analysis paper, “*more than one or multiple chronic conditions*” was the most frequent used expressions, followed by “*comorbidity*” which appeared in 67,557 publications comparing to “*multimorbidity*” which mentioned in 434 publications. Thus, the reference to more than one chronic condition is still interchangeably using different terms in the literatures, and comorbidity was dominantly used compared to multimorbidity because every comorbidity is a multimorbidity. However, for the purpose of this report, multimorbidity will be defined as the presence of two or more chronic conditions (WHO, 2016), while co-morbidity is the associated condition linked to a primary chronic condition (Feinstein, 1970).

Multimorbidity Prevalence

With increased advances in medicine and healthcare delivery, life expectancy in both developed and developing countries has led to a rise in those living with more than one chronic health condition (or multimorbidity) over the life course (WHO, 2016). European countries are among the highest affected countries with multimorbidity. A national health survey conducted in Portugal found that 43.9% of the Portuguese population are living with at least two chronic conditions with a 13.1% expected increase by 2050 (Laires & Perelman, 2019). A recent study published in 2021 based of the SHARE data representing 15 European countries (excluding Ireland) has explored multimorbidity. Outcomes show that prevalence was higher in Portugal, Poland, Czech Republic and Estonia and the lowest in Switzerland, Sweden and Netherlands (Souza et al., 2021). A retrospective cohort study in England stated that 27% of participants had at least two chronic conditions which accounted for 52.9% of GP consultations, 78.7% of prescriptions, and 56.1% of registered hospital admissions (Cassell et al., 2018). In 2022 the Australian Bureau of Statistics reported that nearly half of Australians (47%) have one or more chronic conditions (ABS, 2022). In the USA, the prevalence of multimorbidity among adults is nearly 30% (Boersma, Black, & Ward, 2020), with around 70% of the healthcare spendings in the USA attributed to patients with multimorbidity (Zheng et al., 2021).

In Ireland, a recent study on a representative sample of 6101 older adults demonstrated that multimorbidity has become the standard among the population rather than the exception; and the multimorbidity prevalence among older adults was 73.25% (B. Hernández, Reilly, & Kenny, 2019). Another recent cross-sectional, cross-national study examining older adults multimorbidity prevalence in the USA, Canada, England, and Ireland showed that the USA had the highest prevalence by 60.7%, while Ireland was the lowest with 38.6% (Belinda Hernández et al., 2021). The disparities (38.6%-73.25%) in the multimorbidity prevalence in Ireland between the two previously mentioned studies appears impacted by the number of the diseases included in the analysis, from ten diseases in the 2019's study compared to the thirty-one diseases in the 2021's study.

2.2 Research challenge: Self-management support programmes for patients with multimorbidity

Self-management is defined as "the day-to-day management of chronic conditions by individuals over the course of an illness" (Clark et al., 1991). Self-management includes all the tasks and activities performed at home by the individuals under the guidance of their CN to manage their symptoms, treatment plan, physical or psychological consequences and lifestyle changes (Barlow, Wright, Sheasby, Turner, & Hainsworth, 2002). These activities may include medication management, diet management, connecting with the CN, physical activity adherence and other daily care activities. Self-management aims to empower older adults living with multimorbidity to be actively involved in their case management to live independently and age-in-place (Elzen, Slaets, Snijders, & Steverink, 2007), with self-management programs prescribed to the patients with different chronic conditions at their primary healthcare centres to be performed at their own homes, or after the discharge from in-patient units. Chronic diseases self-management has been proven to improve health outcomes, decrease hospitalisations, unnecessary hospitals visits (Lorig et al., 1999) and healthcare utilisation costs (Panagioti et al., 2014).

Care provided to individuals with multimorbidity

Patients with multiple chronic conditions are treated disease-wise independently, even from their healthcare practitioners (HCPs), despite the fact that PwM have different trajectories of care which if not properly managed, may lead to advancement or further accumulation of diseases across the life course (Vos, van den Akker, Boesten, Robertson, & Metsemakers, 2015). The outcome of which may increase the financial burden for out-of-pocket healthcare expenditure for PwM (Larkin et al., 2022). The lack of multimorbidity focused theoretical and practical management guidelines makes it difficult for PwM to navigate self-management activities, particularly at home. This may lead PwM to reduce self-management activities for some chronic diseases in favour of more acute conditions or they may give preference to self-management activities according to the burden of disease and the easiness to perform related self-management activities. Thus, new interventional tools are needed to foster better understanding of self-management activities for the PwM and their CN including healthcare professionals.

Self-management in Ireland

As ESRs 7 and 8 are based in Ireland, some focus within the deliverable will relate to the Irish context. In Ireland, the national self-management support programme for chronic conditions produced by the Health Service Executive (HSE) is directed towards cardiovascular diseases (CVD), diabetes and respiratory conditions (O'Connell, Mc Carthy, & Savage, 2018). The national self-management programmes however are designed as single disease-specific and not for patients with multimorbidity (O'Connell et al., 2018). The rationale is that designing multiple self-management programs for multiple chronic conditions may create an additional "unsustainable burden" on individuals, so current efforts focus on a "common" self-management support programme for people with multimorbidity (Mullaney et al., 2017) Because there is no national self-management support programme for PwM, the HSE chronic disease self-management steering group recommended the development of supportive tools that may help address the common needs of different multimorbidity, for instance: (1) **patient education** for those who need cardiac and pulmonary rehabilitation and diabetic care, and (2) **lifestyle modification** (smoking, physical inactivity, poor diet, and stress management) which covers a range of disease parameters across conditions (Mullaney et al., 2017) .

Finally, to achieve the above, Irish national self-management support programmes are based on three fundamental care models:

(1) *Person-centred care*: to make the participants involved in their care decisions by empowering their knowledge, education, and communication with healthcare professionals.

(2) *Self-efficacy*: to increase the participants' confidence in their ability to perform tasks or change a specific behaviour.

(3) *Self-care*: to stay physically and mentally fit, action taken to prevent diseases, medication management, treatment of minor diseases, and chronic conditions management.

Self-management and the role of care network (CN)

Formal and Informal caregivers play a key role in helping persons with multimorbidity to follow and support their self-management programmes. A recent review of self-management support (SMS) programmes across five countries-including Ireland- concluded that SMS programmes consist of different cooperation between the healthcare systems, healthcare professionals, social workers, community, and formal and informal caregivers (O'Connell et al., 2018). These actors form an individual's CN.

Informal caregivers are mostly family members who provide unpaid continuous healthcare support at home towards activity of daily livings (ADLs), on the other hand the formal caregivers provide paid support. Despite the efforts of formal and informal caregivers to support the PwM at their homes, a recent systematic review has shown that increased work stress, physical and psychological burdens have led to a significant decrease in the formal caregiver's workforce as well as support provided by informal caregivers (Plöthner, Schmidt, de Jong, Zeidler, & Damm, 2019). According to a recent (Plöthner et al., 2019) systematic review, the burdens on the CN affect the quality of delivered care to the older adults with multiple chronic conditions and the authors urge health services to find new innovative technological solutions to support self-management programmes at home. Furthermore, the review highlighted those older adults with multimorbidity and their CN desired to get real time monitoring solutions to record activities at home and share it among CN. Moreover, users stressed on preserving **privacy** as well as the **usefulness** and **safety** of such technological interventions to help with their adoption (Plöthner et al., 2019). Indeed, a recent EU-funded one-year trial of a digital health platform (ProACT) to support multiple chronic condition self-management among older adults emphasised the importance of **useability**, recommending that digital technological interventions need to be **easy** to use as well as allow for **better communication** among the CN (Doyle et al., 2021).

2.3 Research opportunity: Video-based camera systems to support chronic diseases management

Unlike other ambient assisted living (AAL) sensors, video-based cameras using *Red Green Blue (RGB) sensors or Red Green Blue-Depth (RGB-D) sensors* can provide rich contextual video data that may be helpful for PwM self-management at home supported by their care network (CN). Video-based camera technologies have been used in many AAL systems and in-patient healthcare settings (hospitals, primary care centres or nursing/care homes) for different reasons; like in-patient safety monitoring of fall risks (Cournan, Fusco-Gessick, & Wright, 2018), video communication (Crosby, Hanchanale, Stanley, & Nwosu, 2021), cognition and behaviour monitoring (Abbe & O'Keeffe, 2020) or vital signs monitoring (Molinaro et al., 2022). The collected video-based data can provide rich feedback for the CN to observe, assess and support older adults and deliver tailored-based interventions. The video-based data will also help the healthcare professionals to recall information when needed for progressing assessment follow-ups and case management coordination (Mackenzie & Xiao, 2003).

Many efforts have been exerted to implement a video-based camera system to help patients with a specific chronic condition to self-manage at home and support caregivers to monitor the patient with the chronic condition. For instance, a systematic review about interactive video-based telehealth for diabetic patients concluded that the use of these solutions improved access to quality care and self-management activities at home (e.g. improved the glycaemic control) (McLendon, 2017). Similar positive outcomes were found for video home-based cardiac rehabilitation programs for the cardiovascular diseases (CVDs) patients (Rawstorn et al., 2018), pulmonary rehabilitation for patients with chronic obstructive pulmonary disease (COPD) (Ambrosino, Vagheggini, Mazzoleni, & Vitacca, 2016) and for supporting individuals living dementia at home (Matthews et al., 2015). Aside from chronic disease management home video-based camera systems were also successfully used to monitor the hand functional activities among the spinal cord injuries patients (Likitlersuang, Sumitro, Theventhiran, Kalsi-Ryan, & Zariffa, 2017). Despite these efforts to support patients with specific chronic conditions, little is known about providing these video-based camera systems to the older adults with multimorbidity. So, the main objective of the ESR 7's project is to *advance knowledge in the application and acceptance of camera systems at home to support multimorbidity self-management programmes*. More specifically this includes exploring video-based camera systems to support self-management activities; to identify the effective use of these technologies at home; to define the users' perspective of the technology and their acceptance levels.

2.4 Theoretical framework

When a recent technology is introduced to patients, there are different determinants that may facilitate or hinder their willingness to use and accept this technology. A recent systematic review of the used technology acceptance theories in health informatics found that the Technology Acceptance Model (TAM) theory is the most used theory to frame and explain the willingness of users to use healthcare technologies (Rahimi, Nadri, Lotfnezhad Afshar, & Timpka, 2018). TAM (Figure1) was firstly developed by Fred Davis to explain users acceptance to the use of computers using two beliefs which are *Perceived Usefulness* (PU) and *Perceived Ease of Use* (PEU) (Davis, 1989).

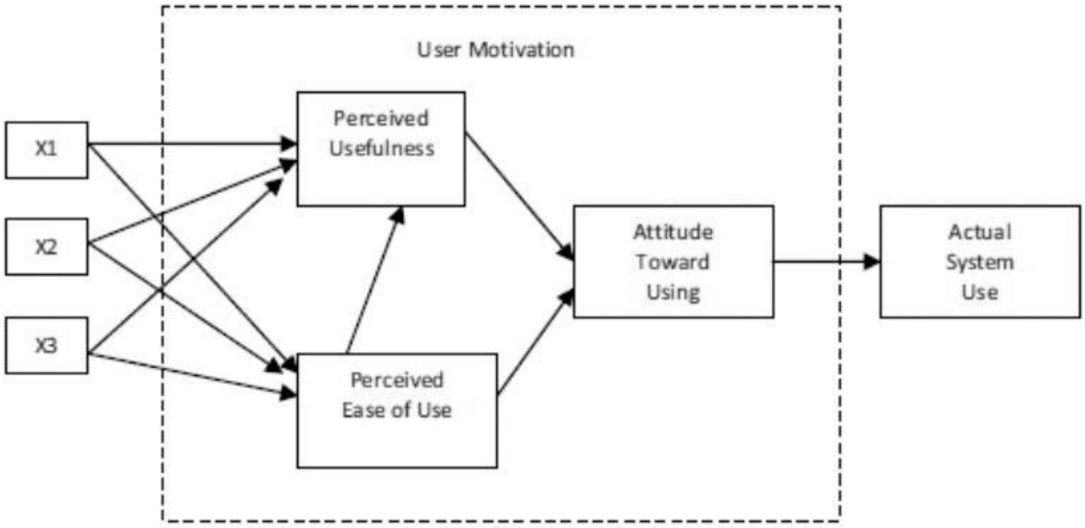

Figure 1: The original TAM by Fred Davis in 1989

Formulated by the TAM, the research proposal of ESR 7 proposes that camera-based technology could be adopted by the participants with multimorbidity if they find it benefits and supports their self-management needs (*Perceived Usefulness*) and if it is easy to use and understandable (*Perceived Ease of Use*).

Over years, TAM has been used across different fields including health informatics to measure and explain the users' motivations to use any new delivered technology and showed high degrees of reliability and validity (Rahimi et al., 2018). With continued efforts to validate TAM across different populations and fields, TAM3 (Figure 2) has been developed to adopt additional technology acceptance determinants (Venkatesh & Bala, 2008) and categorised all the previous TAM determinants to influence the users' *Perceived Usefulness* (PU) and *Perceived Ease of Use* (PEU) into:

(a) *Individual differences*: users' demographics, previous experiences and views, and self-efficacy.

(b) *System characteristics*: system operability, interaction, functionality, and quality.

(c) *Social influences*: subjective norm which refers to person's beliefs about whether people of importance around him/her approve or disapprove a specific issue.

(d) *Facilitating conditions*: i.e., technical support and problem troubleshooting.

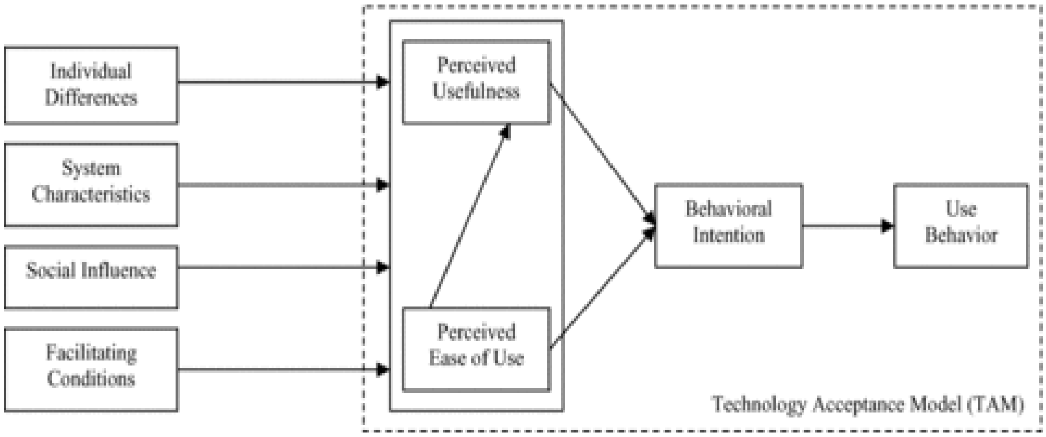

Figure 2: TAM extended version by Venkatesh & Bala in 2008

Indeed, TAM has been used to theoretically formulate the users' intention to use and accept the different range of AAL technologies, however, it has not been used to formulate the older adults' intention to use and adopt a video-based camera system to support their home-based self-management journey. Davis's TAM model was built on the hypothesis that technology use is dedicated to the user's accumulated previous beliefs, the user's current attitude towards this technology, and accordingly the user's intention to use this technology in the future based on the "function" that users will use and the associated "benefits" of these technologies (Turner, Kitchenham, Brereton, Charters, & Budgen, 2010). Previous research showed that users tend to accept technology if it is helpful with an added value to them. For instance, older adults with multiple chronic conditions showed high potential to use a new chat system supported by the Artificial Intelligence (AI) technology because they found it beneficial in enhancing their self-management activities and empowering their disease understanding (Easton et al., 2019).

Adding to Davis's TAM model explanation of the users' intentions to use a specific technology, Venkatesh & Bala proposed the extended version of TAM model and stressed on system operability, interaction, and functionality as other embedded determinants to the users acceptance (Venkatesh & Bala, 2008). Previous studies concluded that the more easier the system is to operate and interact with, the more acceptable it is among the users. Continuing in the context of older adults with multiple chronic conditions, a study demonstrated that participants showed interest to use a mobile phone application because it was simple to use and was helpful in tracking their treatment goals (Steele Gray et al., 2016). Similiarly, a recent qualitative study concluded that participants expressed high intentions to use a web-based healthcare management system thanks to its ease of use and benefits to communicate with their healthcare professionals (Portz et al., 2019).

Even though the TAM models have been the most common used model to formulate the users' technology acceptance in the IT field (Rahimi et al., 2018), they did not cover all the recent supportive technologies in the healthcare delivery field. Earlier studies (Easton et al., 2019; Portz et al., 2019; Turner et al., 2010) elaborated the "functions" and "benefits" of different supportive AAL and wearable technologies to manage patients' chronic conditions, but less is known about the use and acceptance of camera systems in general, especially video-based camera systems, to support chronic conditions management (Wilkowska, Offermann, Spinsante, Poli, & Ziefle, 2022). Thus, TAM may be used to help explain the intention to use the camera system as a new self-management supportive tool for persons with multimorbidity based on the precise system characteristics (interaction and functionality), and the easiness to use this system.

2.5 State-of-the-art of the camera systems to support self-management activities at home for people with multimorbidity: A Scoping Review

To further explore the role and acceptability of camera systems to support home based multimorbidity self-management, a scoping review was conducted. The aim was to identify the current available literature and level of use of video-based camera systems to support older adults' self-management with multiple chronic conditions at home. To the best of our knowledge, this is the first scoping review that was conducted to achieve the following objectives: (a) map the **functions (roles) and**

system characteristics of video-based camera systems for older adults self-managing at home with multimorbidity; (b) explore the different groups of **multimorbidity** in these studies; and (c) explore the **challenges and concerns** from the users' perspectives, and **factors affecting** technology acceptance.

The scoping review was guided by the methodological framework proposed by Arksey and O'Malley (Pollock & Berge, 2018) and its updated version (Tricco et al., 2018). This scoping review used the PEO (Population, Exposure and Outcomes) framework (Table 1) (Pollock & Berge, 2018) to identify the relevant studies.

Table 1: The PEO framework

Criteria	Determinants
Population	Older adults 60 years and older
Exposure (Intervention)	Video-based camera systems
Outcomes	Self-management support programmes for participants with multimorbidity System challenges/acceptance

A pilot search in MEDLINE was conducted to scope definitions and selected terms/keywords. Peer-reviewed articles were searched in February 2022 in the following databases (Figure 3): PubMed, PsycINFO, Cochrane Library, EBSCO host: (MEDLINE, Academic Search Complete, CINAHL complete), MEDLINE (ovid), Ovid SP, Scopus, Embase, Web of Science, BioMed Central, Science Direct, ACM Digital Library, Engineering Village: (Compendex, Inspec) and IEEE Xplore. Reference lists from selected relevant articles were identified for inclusion. Grey literature was identified through Google scholar, ProQuest Dissertations and EMBASE Conference Abstracts. An updated search was executed in June 2022. Databases and grey literature were searched for primary studies that included: (a) older adults aged 60 and older, (b) living at their homes, not in a private institutional healthcare setting, and (c) reported data on the use of video-based camera systems for multimorbidity self-management.

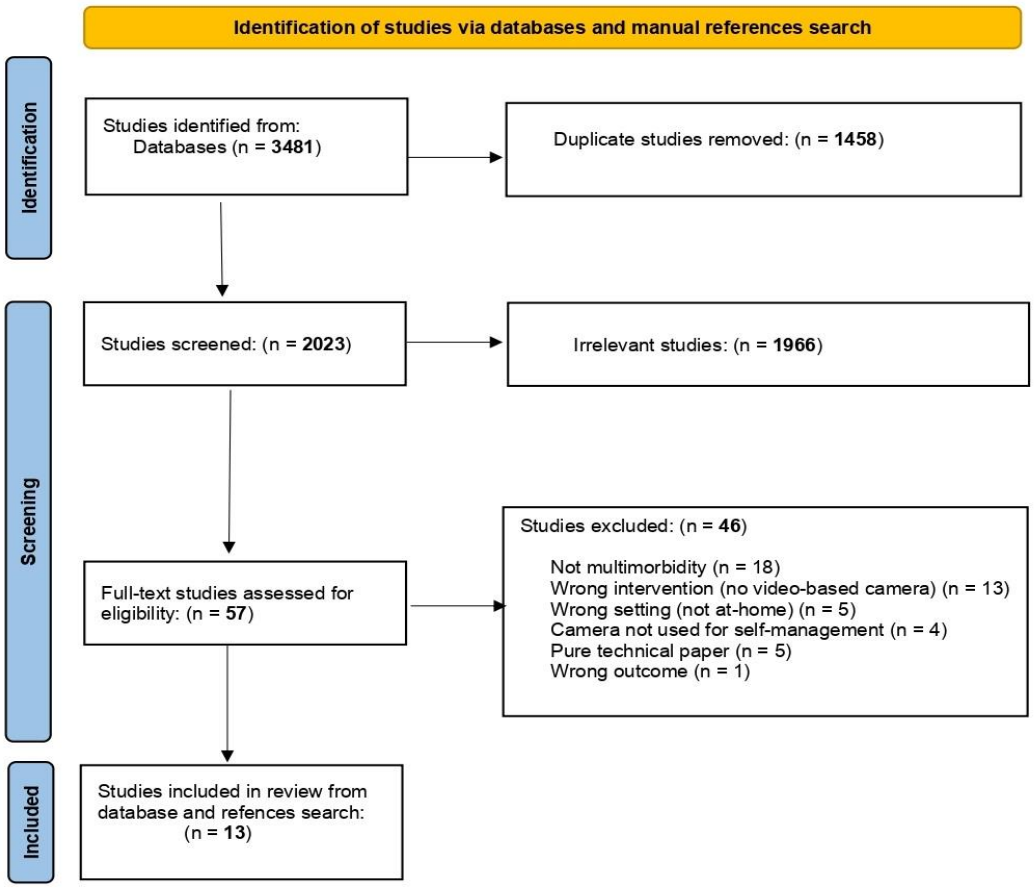

Figure 3: PRISMA flow diagram (PRISMA 2020's comprehensive version)

Scoping Review Results

Technology Acceptance Model (TAM) determinants have been used to report and formulate the scoping review results. The following taxonomy (Figure 4) identified some revealing trajectories of the use of video-based camera systems to support older adults multimorbidity self-management, camera systems characteristics and roles of these camera systems.

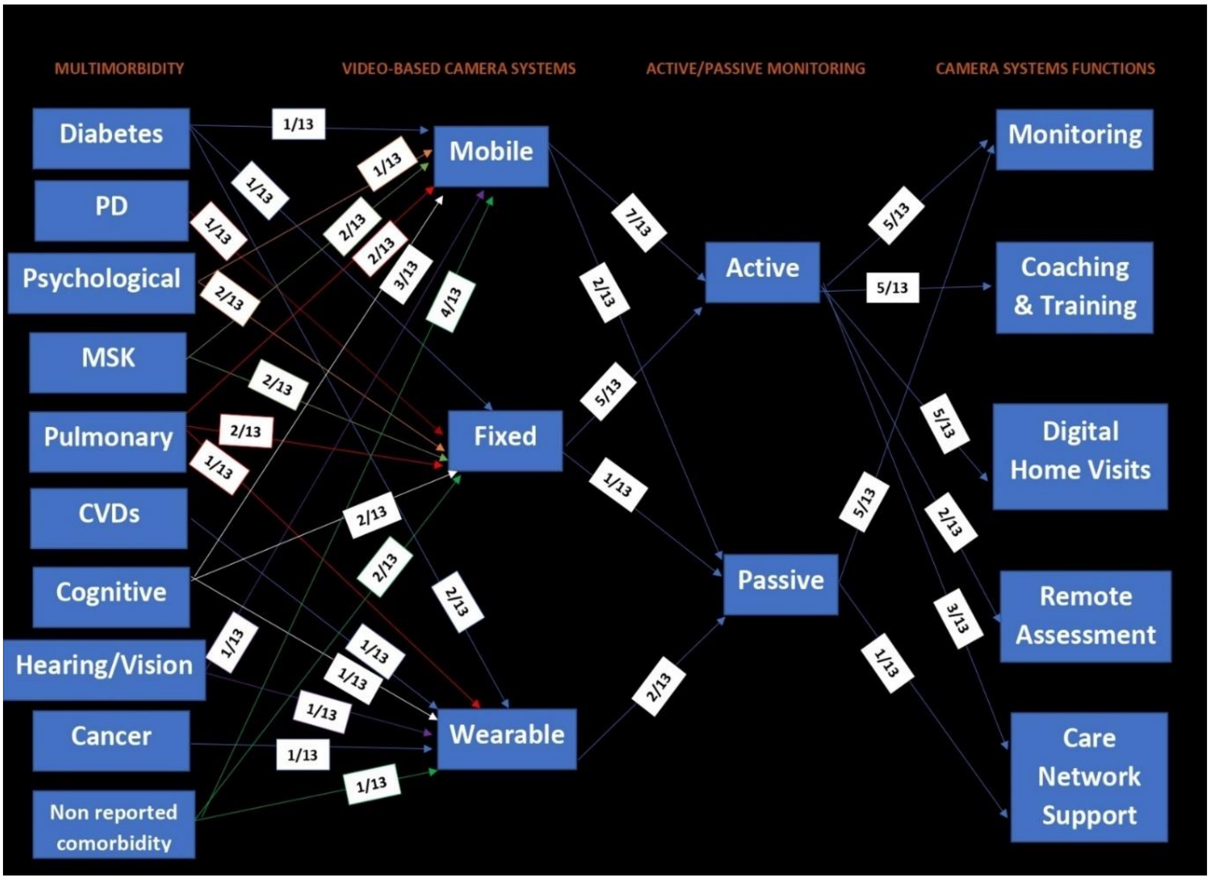

Figure 4: Taxonomy of the used video-based camera systems to support older adults multimorbidity self-management

Note: **PD**=Parkinson's Disease, **MSK**=Musculoskeletal, **CVDs**=Cardiovascular Diseases, **Mobile**=video-based cameras in service robots and all handheld devices (phones or tablet PCs), **Fixed**=video-based cameras mounted to wall/ceiling or web cameras attached to desk PCs or laptops, **Wearable**=video-based cameras worn by the participants, **Active**= camera systems that require active participant interaction with the system to perform specific functions either to report symptoms or case updates, perform a specific task or training and attend a patient education session, **Passive**= camera systems that do not require participant interaction with the system to perform specific functions (mostly passive monitoring)

2.5.1 TAM: System Characteristics

Telemedicine (video conferencing) was the most used video-based camera system for older adults multimorbidity self-management at home (n=8), followed by robots (n=3), then wearable cameras (n=2). Active video-based camera systems were adopted in nine studies, while passive systems were used in four studies. Different video-based camera system characteristics have been identified (Table 2):

Table 2: Video-based camera system characteristics

Video-based camera systems characteristics	n.
Mobile + Active	**7/13**
Fixed + Active	**5/13**
Mobile + Passive	**2/13**
Wearable + Passive	**2/13**
Fixed + Passive	**1/13**

It is noted that the (Fixed + Passive) pattern is the least used system characteristics at home because it may reproduce the sense "Big Brother" or intrusive surveillance, which can lead to a psychological feeling of vulnerability that a mysterious "someone" or "force" is "watching and observing me" with a "control over me" and I have no power to prevent it (Dilmaç & Kocadal, 2019). Indeed, the (Fixed + Passive) camera system pattern is still in use for the surveillance and security purposes in public places, however different healthcare facilities (i.e., nursing homes or the in-patient medical rehabilitation centres) are still using this pattern for specific limited functions, for instance fall prediction/detection (Wang, Ellul, & Azzopardi, 2020) and recently the remote vital signs monitoring (Molinaro et al., 2022). Recently, with the advance of technology inventions and computer vision solutions, wearable cameras and ambient sensors are being used instead of the 'Fixed + Passive' cameras to eliminate the uncomfortable "Big Brother" feeling (Wang et al., 2020), furthermore the remote vital signs monitoring has recently moved away from the 'Fixed + Passive' pattern by using digital mobile phone video cameras or mobile service robots (Molinaro et al., 2022).

2.5.2 TAM: Usefulness- The application of video-based camera systems for multimorbidity self-management

One of the main outcomes of this scoping review was to identify the functions (roles) of the video-based camera systems at homes to support older adults self-managing with multimorbidity. Table 3 shows the functions (roles) of the used video-based camera systems:

Table 3: Functions (roles) of the video-based camera systems

Video-based camera systems functions	n.
Monitoring	**10/13**
Coaching & Training	**5/13**
Digital Home Visits	**5/13**
Care Network Support	**4/13**
Remote Assessment	**2/13**

The monitoring function included monitoring of the participants' sedentary behaviour (lifestyle), diet and physical activity. Coaching & training function was directed to the home-based exercises programs or executing a therapeutic physical therapy rehabilitation program. Digital home visits (DHV) were the digital form of the visits to the healthcare facilities to communicate with the healthcare professionals; and included medication prescription management, case consultation, and patient education sessions. Care network support was responsible for the regular case reporting to the relevant care network actor, either formal or informal. Remote assessment was the function designed to remotely assess the patient using the video-based camera systems either to make sure that the participants are doing the medical rehabilitation program correctly or for the case progress assessment (i.e. diabetic foot care).

2.5.3 TAM: Ease of Use

The scoping review has highlighted the importance of the TAM "ease of use" determinant in the potential acceptance of video-based camera systems by the older adults. Indeed, if the **technology is not easy to use** it may hinder camera acceptance, for instance if an individual experiences; an internet connection drop, irresponsive touch screens, poor battery charging, difficulties with navigating button orientation, and hard-disk failure (Broadbent et al., 2018). Moreover, several articles concluded that a **timed** performance for the camera operation (Alexander et al., 2021) and the level of the exerted **effort** to interact with the camera system may affect the camera acceptance levels, especially with the normal ageing process that affects mobility, power, memory, hearing and vision (Heuvel et al., 2012).

The wider literature on technology acceptance has also shed light on the importance of **exerted efforts** associated with the technology use and concluded that technologies associated with less exerted efforts to use (easy to use) improve an individual's intention to use them (Venkatesh & Davis, 2000). For instance, a study among young adults using an e-learning platform reported that they were more willing to adopt and use the technology when associated with less exerted efforts (Abbad, Morris, & De Nahlik, 2009). On the other hand, the scoping review presented in this deliverable discovered that the "Coaching & Training" function (within camera systems supporting self-management support programmes were among the most used after the "Monitoring" function, despite the fact that the "Coaching & Training" function was associated with high exerted efforts levels from users.

Therefore, it appears that the intention to use camera systems may be increased if associated with "direct benefits", even if this means higher exerted effort levels from the older adults with multimorbidity (Table 4). The distinguished leverage of a "Coaching & Training" function over the other camera systems functions is that the participants with multimorbidity are gaining instant and direct benefits of training (either it is <u>physical activity exercise programmes</u> to increase their physical conditioning or a <u>therapeutic medical rehabilitation programme</u> to self-manage their chronic conditions at home). Thus, providing a "Coaching & Training" function may be helpful to augment future camera system focused self-management support programmes by enhancing the older adults' self-efficacy to increase their confidence in changing areas such as decreasing sedentary behaviour (low physical activity levels) or providing better instruction to perform the home-based self-care or self-tasks.

Table 4: Benefit/effort levels of the active and passive video-based camera systems

	Video-based camera systems functions	Effort description	Related benefits*	Effort levels
Active video-based camera systems	**1- Coaching & Training**	Performing home physical or physiotherapy rehabilitations exercises	Direct	**High**
	2- Digital Home Visits	Visual communication with the CN	Indirect	**Medium**
	3- Care Network Support	Communication (Case reporting)	Indirect	**Medium**
	4- Remote Assessment	Disease assessment	Indirect	**Medium**
Passive video-based camera systems	**5- Monitoring**	Just to turn on/off the camera system to start/end the monitoring session	Indirect	**Low**

*Benefit represents the "perceived usefulness" determinant of the Technology Acceptance Model (TAM). **Direct** benefits on the patients with multimorbidity can be gained instantly through the effect of the self-management support program (i.e. physical conditioning or physiotherapy rehabilitation exercises). **Indirect** benefits are those achieved after communicating with the CN or healthcare professionals (i.e. patient education session, remote assessment, case consultation, or case reporting)

2.6 Future Directions

Presently there is limited research exploring the use of AAL technologies with older adults living at home with multiple chronic health conditions. A need exists for more investigations of the older adults' (including with multimorbidity) experience and acceptance of technological interventions at home (Doyle et al., 2021). Guided by the scoping review results and the Technology Acceptance Model (TAM3) determinants, ESR 7's project will advance knowledge of the influence of camera system functions on the acceptance levels for older adults at home self-managing with multimorbidity. Precisely, the project aims to explore the influences of camera functions on the participants' perceived usefulness (PU) and perceived ease of use (PEU) to support home-based self-management. Currently, a research proposal for the forthcoming research is being under development and will be reported with study outcomes in the update to this deliverable D3.5.

3. Using behaviour change techniques and theory to increase older adults' acceptance of camera-based AAL technologies

3.1 Research challenge: The lagging diffusion of camera-based AAL technologies

Despite the lauded appeals of camera-based AAL technologies for delivering on the ageing-in-place agenda, their interventionist appeals have not been realised. The literature is replete with examples of older adults' outright rejection of camera-based technologies, which frequently allude to aversive notions of being "watched" (Jaschinski & Allouch, 2015) or "spied on" (Jaschinski & Allouch, 2015) by "Big Brother" (Sarkisian et al., 2003). The privacy implications of these technologies are thus a central barrier to their acceptability. Notably, even where concessions to technologically assisted living are made, this willingness often precludes the use of cameras (Demiris et al., 2004; Dermody et al., 2021; Kirchbuchner et al., 2015; Offermann-van Heek et al., 2019). In fact, the privacy intrusive nature of cameras can even result in counterproductive retaliation from older adults, therein jeopardising their effectiveness for supporting independent living and ageing-in-place. In one instructive example, Caine et al. (2012) had older adults engage in a staged activity (i.e., planning a surprise birthday party for a caregiver) in a camera-monitored living lab environment and found that older adults engaged in a range of "privacy enhancing behaviours". These included but were not limited to behaviours such as concealing the camera's lens, turning cameras in opposite, non-person-facing directions, hiding behind furniture, and walking backwards to avoid facial detection. Although these behavioural patterns emerged in a hypothetical living lab context, if extrapolated to real-life settings, such overt privacy enhancing behaviour may occlude the interventionist potential of camera-based AAL technologies.

In sum, the current state of affairs vis-à-vis camera-based AAL technologies is marked by the stagnated diffusion of the technology into target communities of older adults. This sluggish diffusion is primarily attributable to the technology's low levels of acceptability. Therefore, there is a need to develop strategies to enhance older adults' acceptance of camera-based AAL technologies. This is the central aim of ESR 8's research. Specifically, the project will aim to:

> *Use behaviour change theory to understand how best to facilitate older adults' acceptance of camera-based AAL technologies, and to locate, understand, and empirically validate mechanisms of action through which interventions can enhance older adults' acceptance of the technology.*

3.2 Research approach: The experimental medicine approach to changing older adults' AAL technology acceptance behaviour

To achieve this research aim, the ESR 8 project will approach non-acceptance of camera-based AAL technologies as a behavioural problem. It aims to move older adults from a position of low acceptance (and consequently, low uptake) to a position of willing acceptance (and consequently, willing uptake based on their consent); the research' central concern is on behaviour change.

The experimental medicine approach to changing behaviour will be used to conceptualise and structure all research processes. Pioneered by the Science of Behaviour Change Programme, the experimental medicine approach advocates a theory-led, mechanistic approach to changing behaviour (Nielsen et al., 2018). The approach is founded on the principle that interventions designed to change behaviour should be informed by a hypothesis about why a behaviour exists and how best to change it – i.e., a mechanisms-of-change hypothesis. The experimental medicine approach involves four key stages:

1. Identify the factors (i.e., barriers and facilitators) related to the behavioural outcome of interest – i.e., older adults' acceptance of camera-based AAL technologies.

2. Measure the mechanism of interest using valid and reliable ways, to test for meaningful associations between mechanism and outcome.

3. Manipulate the mechanism.

4. Examine whether manipulation of the mechanism results in the desired behaviour change.

3.3 Theorising older adults' acceptance of camera-based AAL technologies

Early strides have been made in developing an empirical understanding of the factors that influence older adults' acceptance of camera-based AAL technologies. These reveal, for instance, that adults' resistance to camera-based AAL technologies is not unyielding. There are important trade-offs that occur in older adults' cognitive assessments of these technologies, where the risks of accepting and using the technology are deliberately weighted against the benefits of doing so (Townsend et al., 2011). For instance, studies have shown that older adults are typically inclined to sacrifice valued notions of privacy and autonomy for comparatively heftier benefits such as improved health, safety, and independence (Peek et al., 2015). Other studies demonstrate that older adults are typically inclined to accept the technology if this is seen as the sole alternative to transitioning to residential care (Sánchez et al., 2019). Still others denote that privacy concerns are marginally less important when juxtaposed against a genuine need for care. As illuminated by one older adult in Sarkisian et al.'s (2003) qualitative analysis of attitudes towards a camera-monitored home, "if you need it, privacy goes out the window".

Evidently, there are a panoply of factors that determine whether camera-based AAL technologies are accepted or rejected by older adults. Yet, there is little scholarly attention on the antecedents to such (non-)acceptance, and where this has been enacted, studies feature a narrowed focus on the technology's privacy implications and utilitarian value. For instance, according to Davis' (1989) seminal Technology Acceptance Model, whether a technology is accepted or rejected is determined by its usefulness and ease-of-use, as perceived by target users. On this account, studies have attributed the sluggish diffusion of camera-based AAL technologies to the fact that homes might need to be specially retrofitted for un-occluded camera-enabled monitoring, or to the fact that complex user interfaces may be seen as onerous and insurmountable for frail older adults (Jaschinski & Allouch, 2015; Normie, 2011).

While informative, these studies give little credence to the range of cognitive, affective, social, and environmental determinants of older adults' technology acceptance decisions. For example, the critical ageing scholarship alludes to stigmatising precepts inscribed into assistive technology, where older adults are construed as having "deficits" that can be aptly compensated for through the use of technology (Neven & Peine, 2017). Yet, as these imageries of dependency and decline do not necessarily reflect the lived realities of older adults, many vehemently contest their need for such technologies (Aminzadeh & Edwards, 1998; Forlizzi et al., 2004; Wu et al., 2016). Additionally, despite their putative functions for personalised caregiving, AAL technologies can be seen as "cold", "impersonal", and "sterile" and thus as improper substitutes for human caregiving (Ziefle & Valdez, 2017). Indeed, camera-based AAL technologies have been rejected on account of their perceived inadequacy to subsume human caregiving roles (Ghorayeb et al., 2021; Maan & Gunawardana, 2018). Evidently, then, there exists a range of determinants of older adults' acceptance of camera-based AAL technologies that span a theoretical limit far wider than that conveyed in traditional technology acceptance models.

3.3.1. Identifying the barriers and facilitators to older adults' acceptance of camera-based AAL technologies: A scoping review

Efforts to change behaviour must necessarily be underpinned by an understanding of the determinants of said behaviour (Michie et al., 2018). Extrapolated to the AAL technology acceptance domain, strategies aimed at enhancing older adults' acceptance of camera-based AAL technologies must be informed, in the first instance, by a theoretical understanding of the various determinants of said acceptance. To date, however, there have been few systematic investigations of these factors, with studies focusing primarily on pragmatic determinants such as privacy and usability issues (Ziefle & Wilkowska, 2014). Without a foundational understanding of the determinants of older adults' acceptance of camera-based AAL technologies, developers have little guidance on optimal design and dissemination techniques, which may account for the technology's lagging diffusion.

As a first step in an experimental approach to changing older adults' AAL technology acceptance behaviour, a scoping review of the barriers and facilitators to older adults' acceptance of camera-based AAL technologies was conducted. A scoping review was appropriate in light of the embryonic and methodologically heterogenous nature of scholarship pertaining to older adults' acceptance of camera-based AAL technologies; relevant literature can be found in fields including human-computer interaction, engineering, and gerontology research (Berridge & Wetle, 2020; Demiris et al., 2008; Gibson et al., 2015; Vaziri et al., 2017). As scoping reviews provide a systematic means to synthesise fragmented research perspectives as well as to identify factors (e.g., barriers and facilitators) related to a concept (e.g., acceptance of camera-based AAL technologies, Munn et al., 2018), a scoping review was deemed most suitable for the current research purpose.

ESR 8's scoping review is distinct from ESR 7's as it explores the range of factors that influence older adults' acceptance of camera-based AAL technologies *beyond* those captured in the TAM - that is, beyond the *perceived usefulness, perceived ease of use,* and *intention* to use the technology. Nonetheless, it complements the efforts of ESR 7's scoping review by highlighting other potentially important cognitive, affective, social, and environmental determinants of acceptance.

Analyses of behavioural determinants benefit from an explicit use of theory (Michie et al., 2018). Theories of behaviour help to explain and predict why a behaviour exists, and when and how behaviour change occurs (Michie et al., 2014). Theory therefore provides a structured framework against which factors causally related to a particular behaviour can be understood and targeted for change (McSharry et al., 2020).

As such, in the context of our scoping review, it was decided a priori to map identified barriers and facilitators onto the Theoretical Domains Framework (TDF). The TDF is a popular behavioural framework outlining 14 key theoretical determinants of behaviour: (i) Knowledge; (ii) Skills; (iii) Social/Professional Role and Identity; (iv) Beliefs about Capabilities; (v) Optimism; (vi) Beliefs about Consequences; (vii) Reinforcement; (viii) Intention; (ix) Goals; (x) Memory, Attention, and Decision Processes; (xi) Environmental Context and Resources; (xii) Social Influences; (xiii) Emotion; and (xiv) Behavioural Regulation (Cane et al., 2012). By specifying explicit links between the psychological constructs (e.g., "skills") and behaviour (e.g., "technology acceptance"), the TDF provides a systematic, evidence-based framework to facilitate exploration of barriers and facilitators to particular behaviours (Atkins et al., 2017). Classifying barriers and facilitators according to the TDF also enables the selection of targeted behaviour change techniques (e.g., “training programmes for technology upskilling”) with robust theoretical linkages to determinant constructs (Michie, 2008). Thus, the use of theoretical frameworks such as the TDF facilitate the design of behaviour change interventions and allows for a precise understanding of the mechanistic processes underpinning behaviour change, which in turn benefits intervention efficacy and generalisability (Handley et al., 2016).

The scoping review was conducted in accordance with established methodology from the Joanna Briggs Institute (Peters et al., 2020). Six key databases (Medline, CINAHL, Embase, Web of Science, ACM Digital Library, and IEEE Xplore Digital Library), the grey literature (Google Scholar), and reference lists were searched for primary studies that: (i) included older adults aged 60 and above as participants, (ii) reported data on barriers and facilitators to the acceptance of camera-based AAL technologies, and (iii) sampled from private residential settings (i.e., the home environment). For pragmatic reasons, the review excluded studies investigating wearable, given their differential privacy implications compared to ambient cameras that are “embedded in the environment” (Cardinaux et al., 2011). Specifically, compared to wearable cameras, ambient cameras are amenable to sensitive information such as a person’s facial features and attire (Ozcan et al., 2013). As such, individuals tend to exhibit lower privacy concerns when contemplating usage of wearables compared to ambient cameras (Ozcan et al., 2013), testifying to differential antecedents to older adults’ acceptance of these technologies. For evaluative parsimony, then, this review only included studies that evaluated the acceptability of ambient cameras. The initial database search was conducted in September 2021, with an updated search in May 2022. No date or language restrictions were applied.

Following standard in-duplicate data screening and extraction procedures, barriers and facilitators were identified and mapped onto the TDF. Thereafter, inductive analysis was used to specify important barrier and facilitator subthemes within each TDF domain. Figure 5 indicates progress through the review.

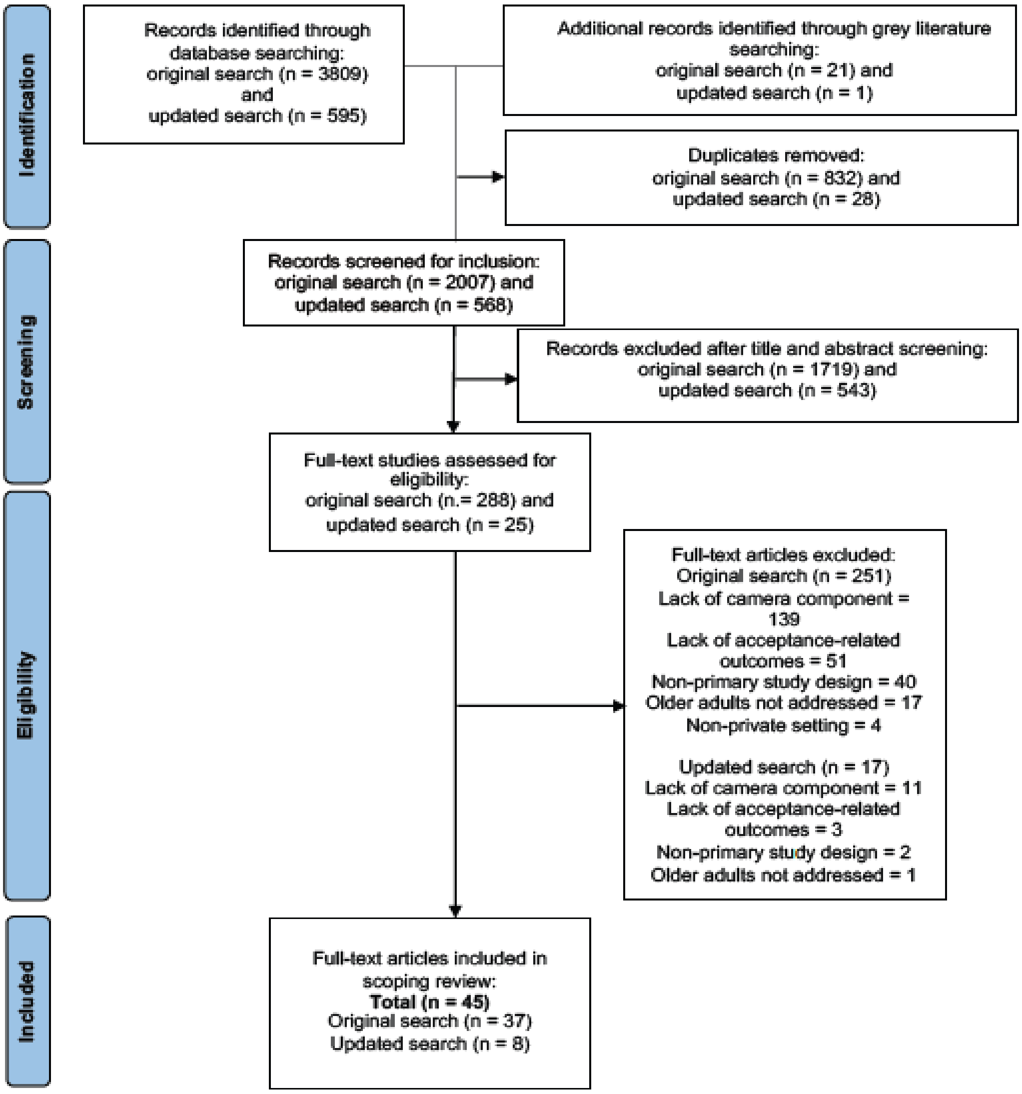

Figure 5: PRISMA flow diagram

Of the final analytic pool of 45 studies, a total of 27 barriers and facilitators were identified that mapped onto 12 domains of the TDF. Table 5 summarises key barriers and facilitators.

Table 5: Barriers and facilitators to older adults' acceptance of camera-based AAL technologies categorised by TDF domain, presented in order of importance (i.e., coding frequency)

TDF domain	Barriers	Facilitators
Beliefs about consequences (CF = 209, 30.8%)	Privacy and data protection concerns	Perceived utility
	Technological issues and burdens	Anonymization of camera-acquired images
	Perceived lack of utility	Assurance of data security
Environmental Context and Resources (CF = 99, 14.6%)	Costliness	Unobtrusiveness
	Low ease-of-use	High ease-of-use
	Obtrusiveness	
	Lack of accommodating infrastructure at home	
	Lack of integration with existing lifestyle	
Social/Professional Role and Identity (CF = 84, 12.4%)	Concern about loss of autonomy and/or dignity	Perceived need
	Perceived lack of need	
	Perceived stigma	
	Assimilation of "old fashioned" identity	
Social Influences (CF = 69, 10.2%)	Preference for human-provided care and interaction	Perceived capacity to facilitate social relationships
	Concern about caregiver burdens	Perceived potential to relieve caregiver burdens
		Normative signals for uptake
	Presence of existing care support network	
Reinforcement (CF = 61, 8.98%)	Lack of prior experience with (assistive) technology	Prior experience with (assistive) technology
		Prior health adversity
		Prior receipt of care at home
	Lack of prior health adversity	
Beliefs about capabilities (CF = 44, 6.48%)	Perceived lack of control over system operations	Perceived control over system operations
	Perceived lack of self-efficacy	
Memory, Attention, and Decision Processes (CF = 43, 6.33%)	Perceived lack of current (versus future) need	Willingness to trade-off privacy for perceived utility
	Self-other distinction in perceived need	
Emotions (CF = 30, 4.42%)	Discomfort around cameras	Fear of being helpless during emergencies
	Technology anxiety	
	Embarrassment or shame	
Knowledge (CF = 16, 2.36%)	Lack of knowledge and/or understanding	
Goals (CF = 10, 1.47%)		Desire to avoid transition to institutional care
Optimism (CF = 9, 1.33%)	Unrealistic optimism about health and ageing	
Skills (CF = 5, 0.74%)	Lack of skills for competent usage	

Note: CF = coding frequency, i.e., the total number of times a barrier/facilitator was coded, expressed as absolute numbers and as a percentage of the total number of codes.

This scoping review is the first attempt to systematically identify and theoretically synthesise the barriers and facilitators to older adults' acceptance of camera-based AAL technologies. To our knowledge, it is also the first TDF-based synthesis of the determinants of older adults' acceptance of AAL technologies or assistive technologies more generally. The results outline an array of barriers and facilitators spanning 12 theoretically robust domains of behavioural influence. Importantly, the identified factors pertain not only to pragmatic issues in usability and technical feasibility, but also to a plethora of cognitive, emotional, and psychological factors that have significant bearing on older adults' acceptance decisions.

Testifying to the importance of utilitarian considerations in older adults' acceptance of camera-based AAL technologies, barriers and facilitators were predominantly represented in the *Beliefs about Consequences* domain. Privacy and data protection concerns predominated older adults' reasons for rejecting the technology. Importantly, however, these concerns were not unyielding and were mitigated through the use of privacy-enhancing filters as well as by ensuring secure processes in data acquisition, storage, and transmissions. Other pragmatic barriers included the cost and ease-of-use of the technology. Acceptance was also diminished where infrastructural requirements for the technology were high (e.g., need for Internet connectivity at home, space requirements, etc.).

Importantly, however, acceptance depended not only on the technology's utilitarian adequacy but also on how it fits within the occupied or desired identities of older adults. Barriers and facilitators were frequently represented in the *Social/Professional Role and Identity* domain, such that older adults who did not see themselves as needing the technology were less inclined to accept it. Many believed that they were still "young and capable" (Ghorayeb et al., 2021), contrary to the "older [and] more infirm" (Grace et al., 2017) imageries of intended users of the technology. Others saw the technology as stigmatising and did not want visitors to "think [they were] crazy" (Demiris et al., 2009) for using the technology.

By highlighting the mechanisms of action through which older adults' acceptance of camera-based AAL technologies arise, results of the scoping review usefully contribute to an understanding of how best to augment acceptance. Primarily, these involve the use of unobtrusive design, such as where cameras are “hidden behind mirrors” (Krafft & Coskun, 2009), “incorporated into furniture” (Grace et al., 2017), or miniaturised (Lapierre et al., 2018). This is because the stigmatising quality of the technology was found to be intimately linked to its visibility to others. As such, ambient cameras that “hang unaesthetically” (Krafft & Coskun, 2009) were particularly aversive for older adults, many of whom worried that visible cameras would betray their plight (e.g., chronic disease or disability) to others. In such ways, cameras that were “out of sight [were also] out of mind” (Grace et al., 2017), allowing older adults to go about their daily lives without the self-consciousness that might otherwise circumvent their acceptance of camera-based AAL technologies. Additionally, subsidised, low-complexity, and easy-to-use systems were better received than their more cumbersome counterparts (Maan & Gunawardana, 2018; Mihailidis et al., 2008). Results therefore suggest that older adults’ *Environmental Context and Resources* can be leveraged to enhance acceptance.

Overall, the results of the scoping review are informative as they reveal a range of psychosocial and contextual antecedents to acceptance that span a theoretical remit far wider than that which has been traditionally portrayed in technology acceptance models. Findings thus stand to inform the development and dissemination of more acceptable – and thus more widely used – camera-based AAL technologies.

3.4 A behaviour change strategy to increase older adults’ acceptance of camera-based AAL technologies: The role of the “future self”

The barriers and facilitators identified in ESR 8’s scoping review illuminate numerous mechanisms of action that can be targeted to affect behaviour change – that is, to increase older adults’ acceptance of camera-based AAL technologies. Interestingly, while mechanisms such as older adults’ *Beliefs about [the] Consequences* of using the technology can be arguably targeted using pragmatic strategies such as by using privacy-preserving filters and secure data transmission processes, results also revealed a variety of non-pragmatic mechanisms that may be of substantive importance for changing older adults’ orientations towards camera-based AAL technologies. Chiefly, these mechanisms were captured in the *Memory, Attention, and Decision Processes* domain of the TDF.

A notable barrier to older adults' acceptance of camera-based AAL technologies was captured in a "perceived lack of current (versus future) need" subtheme, which referred to older adults' tendency to defer their need for the technology into the distant future. A consistent pattern across the reviewed studies was that older adults tended to express a willingness to use the technology "at a later point" (Demiris et al., 2008), "at a later time, when they were older" (Dermody et al., 2021), or only "in the future when required" (Elers et al., 2018). Consequently, few older adults were willing to use the technology in the present day (Claes et al., 2015). This "not yet" attitude is a recurring empirical phenomenon, having been denoted across a series of studies as a barrier to older adults' acceptance of AAL technologies more generally (Astell et al., 2020).

Another marked barrier to acceptance was subsumed under a "self-other distinction in perceived need" subtheme, which reflected older adults' tendency to defer the need for camera-based AAL technologies onto people *other than themselves.* Frequently, older adults cited "friends" (Demiris et al., 2008) and "other people" (Jaschinski & Allouch, 2015; Sánchez et al., 2019) for whom the technology would be beneficial, whilst simultaneously denouncing their own need for the technology. As illuminated in one quote: "There are many people who would benefit a great deal from this. I don't think I need this" (Demiris et al., 2009).

Upon further contemplation and with careful consideration of the psychological and behavioural literature, ESR 8 proposed a psychological construct that could plausibly account for the abovementioned barriers to older adults' acceptance of camera-based AAL technologies: *future self-continuity.* Defined as the felt psychological connectedness between present and future selves (Urminsky, 2017), or the sense of persistence of one's selfhood from the present to the future (Sokol & Serper, 2020), future self-continuity has important implications for a range of health-related behaviours. This is because most health behaviours involve costs and benefits that occur at different points in time (i.e., they are characterised by *intertemporality),* requiring that individuals act conscientiously in the present in order to secure better rewards for themselves in the future (Chabris et al., 2010). In other words, healthful behaviours require the current self to endure immediate sacrifice in order to benefit the future self (Ersner-Hershfield et al., 2009).

Importantly, studies have demonstrated that future self-continuity varies as a function of time, such as individuals typically feel more continuous to selves that are closer rather than further away in time (Bartels & Urminsky, 2011; Ersner-Hershfield et al., 2009). Consequently, individuals who lack future self-continuity may be reticent to endure immediate sacrifices on behalf of their future selves, preferring to favour the interests of their present selves instead (Ersner-Hershfield et al., 2009; Hershfield et al., 2012). For instance, studies demonstrate that people who feel less (versus more) connected to their future selves tend to save more for retirement (Ersner-Hershfield et al., 2009) and engage in more physical activity (Rutchick et al., 2018). Importantly, recent theorising suggests that future self-continuity implicates not only perceived similarity but also vivid imaginaries and affective dispositions towards the future self (Bixter et al., 2020; Sokol & Serper, 2020). Specifically, studies demonstrate that individuals feel closer to not only their similar future selves (Ersner-Hershfield et al., 2009) but also those that are more vividly imagined (Hershfield et al., 2011) and seen in more positive light (Wilson & Ross, 2001). Indeed, there is evidence that vivid conceptualisations of the future self helps benefit forward-looking behaviours such as academic effort (Blouin-Hudon & Pychyl, 2017) and abstinence from drugs and alcohol (Shen et al., 2022). Furthermore, individuals who cite greater (versus less) care for the future self have been shown to consume less alcohol, have better dietary behaviours, and engage in more physical activity (Brotkin, 2019). These findings suggest that when future selves are seen as more similar to present selves, viewed in more vivid and salient terms, and evoke more positive affect, individuals are more willing to make immediate sacrifices to secure better outcomes for these future selves. Conversely, future selves to whom individuals experience little continuity may be relatively less likely to evoke such sacrificial treatment.

That people can feel more or less continuity to their future selves may have important implications for older adults' acceptance of camera-based AAL technologies. This is because the decision to accept and adopt the technology is an intertemporal one, involving trade-offs between sooner and later outcomes, or outcomes for sooner and later *selves.* Specifically, while the costs of acceptance (e.g., invaded privacy, monetary costs) are necessarily endured by the current self, the corresponding benefits (e.g., long-term improvements in wellbeing and independence) largely accrue to the future self. Accepting the technology therefore requires that older adults defer benefits to, and endure costs on behalf of, their future selves. However, just as people have little reason to make sacrifices on behalf of strangers (Ersner-Hershfield et al., 2009), older adults may have little cause to ensure the present-day costs associated with using the technology only to secure greater benefits for future selves to which they have no affinity. On this account, future self-continuity may represent a mechanism of action underpinning older adults' acceptance of camera-based AAL technologies, and consequently, may be targeted in an acceptance-promoting intervention.

3.4.1. The role of future self-continuity in older adults' acceptance of camera-based AAL technologies: A descriptive correlational study

To the best of our knowledge, no study has examined the association between future self-continuity and older adults' acceptance of assistive technology, not least their acceptance of *camera-based* AAL technologies. To this end and as part of the second step in the experimental approach to behaviour change, a descriptive correlational study was conducted to examine this association, with a view to establishing future self-continuity as a mechanistic target underpinning older adults' acceptance of camera-based AAL technologies.

The study took the form of an online questionnaire disseminated using the survey platform Qualtrics. Participants were community-dwelling older adults aged 60 and above. Participants were recruited using Amazon MTurk, an online crowdsourcing platform that facilitates the recruitment of participants to tasks requiring human intelligence (Berinsky et al., 2012). After providing informed consent, eligible participants completed measures of future self-continuity (Sokol & Serper, 2020), privacy concerns regarding camera-based AAL technologies (Jaschinski et al., 2021), perceived usefulness of the technology (Jaschinski et al., 2021), and acceptance of the technology. As in prior research (Claes et al., 2015; Mihailidis et al., 2008), acceptance was assessed using a single Likert-scale item asking participants about the extent to which they would be willing to install the technology in their homes; willingness-to-install was taken as a proxy for acceptance. Future self-continuity was measured using Sokol and Serper's (2020) Future Self-Continuity Questionnaire (FSCQ), which comprises items assessing three distinct substrates of future self-continuity: similarity to the future self, vividness of the future self, and positivity towards the future self. Responses on the FSCQ generate an overall FSCQ score as well as three subscale scores corresponding to each of three similarity, vividness, and positivity substrates. Conduct of the study received approval from the Ethics Committee at the School of Nursing and Midwifery, Trinity College Dublin, Ireland.

Results from a final analytic sample of n = 183 corroborated our key hypothesis: future self-continuity (i.e., the full FSCQ score) was significantly and positively associated with older adults' acceptance of camera-based AAL technologies ($r = .300$, $p < .001$). Interestingly, FSCQ-vividness ($r = .383$, $p < .001$) and FSCQ-positivity ($r = .319$, $p < .001$), but not FSCQ-similarity ($r = .114$, $p = .126$), was positively associated with acceptance. This suggests that older adults' acceptance of camera-based AAL technologies is benefited by vivid and positive conceptualisations of their future selves but is relatively unaffected by felt similarity to their future selves. Table 6 presents the results of correlational analyses.

Table 6: Zero-order and partial correlations between key study variables

	FSCQ-similarity	FSCQ-vividness	FSCQ-positivity	Privacy concerns	Perceived usefulness	Acceptance
Full FSCQ	$r = .883$, $p < .001$***; $r^{\#} = .883$, $p < .001$***	$r = .849$, $p < .001$***; $r^{\#} = .846$, $p < .001$***	$r = .840$, $p < .001$***; $r^{\#} = .836$, $p < .001$***	$r = .415$, $p < .001$***; $r^{\#} = .454$, $p < .001$***	$r = .515$, $p < .001$***; $r^{\#} = .506$, $p < .001$***	$r = .300$, $p < .001$***; $r^{\#} = .266$, $p < .001$***
FSCQ-similarity		$r = .582$, $p < .001$***; $r^{\#} = .577$, $p < .001$***	$r = .569$, $p < .001$***; $r^{\#} = .563$, $p < .001$***	$r = .384$, $p < .001$***; $r^{\#} = .409$, $p < .001$***	$r = .349$, $p < .001$***; $r^{\#} = .342$, $p < .001$***	$r = .114$, $p = .126$; $r^{\#} = .085$, $p = .255$
FSCQ-vividness			$r = .721$, $p < .001$***; $r^{\#} = .715$, $p < .001$***	$r = .335$, $p < .001$***; $r^{\#} = .366$, $p < .001$***	$r = .534$, $p < .001$***; $r^{\#} = .525$, $p < .001$***	$r = .383$, $p < .001$***; $r^{\#} = .364$, $p < .001$***
FSCQ-positivity				$r = .324$, $p < .001$***; $r^{\#} = .361$, $p < .001$***	$r = .501$, $p < .001$***; $r^{\#} = .494$, $p < .001$***	$r = .319$, $p < .001$***; $r^{\#} = .293$, $p < .001$***

Privacy concerns	r = .426, p < .001***; $r^{\#}$ = .456, p < .001***	r = .009, p = .903; $r^{\#}$ = .069, p = .354
Perceived usefulness		r = .383, p < .001***; $r^{\#}$ = .360, p < .001***

Values are Pearson's correlation coefficients. #Partial correlation coefficient controlled for income level and chronic disease status as covariates. *p < .05, **p < .01, ***p < .001.

Correlational findings were corroborated by the results of subsequent logistic regression models, which found positive predictive effects of the full FSCQ (β = 1.10, *SE* = .297, *p* < .001, OR = 2.99, 95% CI [1.67, 5.35]), FSCQ-vividness (β = 1.17, *SE* = .257, *p* < .001, OR = 3.21, 95% CI [1.94, 5.31]), and FSCQ-positivity (β = 1.13, *SE* = .287, *p* < .001, OR = 3.09, 95% CI [1.76, 5.43]) on acceptance. By contrast, how similar older adults felt to their future selves did not significantly predict their acceptance of camera-based AAL technologies (β = .418, *SE* = .213, *p* = .05, *OR* = 1.52, 95% CI [1.00, 2.31]). All statistical results remain unchanged in significance and direction following the inclusion of the demographic covariates chronic disease status and income.

Overall, results of the descriptive correlational study support our conjecture that older adults' resistance to camera-based AAL technologies can be attributed at least in part to a lack of future self-continuity. Older adults who had less (versus more) vivid and positive conceptions of their future selves were less willing to accept camera-based AAL technologies in present day. These findings situate future self-continuity – specifically, its vividness and positivity components as a potentially viable target for interventions aimed at promoting older adults' acceptance of camera-based AAL technologies.

3.4.2. Self-continuity-enhancing strategies to promote acceptance of camera-based AAL technologies

The extant work of ESR 8 has established future self-continuity as a potentially viable target for interventions aimed at promoting older adults' acceptance of camera-based AAL technologies. In line with steps 3 and 4 in the experimental medicine approach to behaviour change, future work will explore the effectiveness of manipulations of future self-continuity for promoting older adults' acceptance of camera-based AAL technologies. This work will also examine the extent to which such manipulations improve acceptance *via reduced privacy concerns* vis-à-vis the technology.

Promisingly, future self-continuity has been established as a malleable behavioural target in prior studies, which demonstrate that experimentally enhancing the vividness and positivity with which individuals experience their future selves can benefit forward-looking behaviours such as exercise (Rutchick et al., 2018), saving for retirement (Hershfield et al., 2011; Macrae et al., 2017) and abstinence from drugs and alcohol (Shen et al., 2022). To this end, a forthcoming study will aim to develop a behaviour change intervention aimed at enhancing said acceptance via experimental manipulations of future self-continuity.

3.4.3. Next steps: Examining the effect of a "future-self intervention" on older adults' acceptance of camera-based AAL technologies

Attempts to increase individuals' continuity to their future selves have benefitted a range of forward-looking behaviours across health and non-health domains (Hershfield et al., 2011; Macrae et al., 2017; Rutchick et al., 2018; Shen et al., 2022). To the best of our knowledge, however, no such intervention has been attempted in the context of technology acceptance among older adults. Nonetheless, the robust relationships between future self-continuity and acceptance revealed in our correlational study hint at potentially substantive effects of a self-continuity-enhancing intervention on older adults' acceptance of camera-based AAL technologies.

At present, a protocol for the forthcoming experimental study is still under development. Nonetheless, we expect that the strategies employed in our experimental study will be based on previous interventional strategies to enhance future self-continuity, such as vividly imagining the future self (Blouin-Hudon, 2015; Raposo, 2019), writing a letter to the future self (Chishima & Wilson, 2021; Rutchick et al., 2018; van Gelder et al., 2013), and/or completing a "MadLibs"-style question-and-story exercise designed to prompt vivid thinking about the future self (Shah et al., 2022). A priori, it is anticipated that the latter strategy will be most suited to the context of AAL-relevant decision-making among older adults and will thus be the preferred mode of intervention. Specifically, the developers of the “future-self intervention” used a tablet-based application in which participants responded to questions about their future selves. Responses were then piped into a personalised story about participants’ envisaged futures which participants then read aloud. Promisingly, participants in the intervention group were significantly more likely to sign up to a retirement savings programme compared to those in a control (no intervention group). This finding suggests that thinking about the future self can have beneficial effects on forward-looking behaviour, presumably due to heightened vividness of the future self (Shah et al., 2022). We will thus explore the feasibility of adapting Shah et al.’s future-self intervention to the specific context of older adults’ decision-making surrounding acceptance and/or uptake of camera-based AAL technologies. It is hypothesised that older adults who undergo the future-self intervention, which will be designed to prompt concrete and vivid thinking about their future selves, will express significantly greater acceptance of camera-based AAL technologies compared to those in a control group who do not undergo the intervention. Outcomes of the study will be reported in the update to this deliverable, D3.5.

4. Evaluation of strategies most appropriate to address end-users privacy and ethical concerns for camera use within the home

4.1 Technical strategies to reduce privacy concerns surrounding camera-based AAL technologies

This section will explore the privacy and ethical issues related to ESR 7’s and ESR 8’s projects, and their future research planned to address the end-user’s privacy and ethical concerns for camera use at home. It is worth mentioning that D1.4 will focus on the empirical profiles for privacy-aware and acceptable research and innovation in video-based technologies for healthcare and AAL, while D1.5 will cover the acceptance cartography of the video-based AAL applications.

Recently, with the progress of computer vision and artificial intelligence research, technological solutions have to comply with the principles of privacy by design and by default, as established by the General Data Protection Regulation (GDPR)[1]. Literature suggests capturing only the required data (data minimisation - Article 5(1)(c) of the GDPR and Article 4(1)(c) of Regulation (EU) 2018/1725) with the least privacy invasion possible for more acceptable and successful camera-based intervention for multimorbidity self-management at home (Sun et al., 2015; Yin et al., 2018). Recent publications highlighted the possible privacy solutions that could be implemented (Climent-Pérez & Flórez-Revuelta, 2021; Ravi et al., 2021):

1-*Intervention*: As an intervention, the camera is prevented from using the recording function (i.e., a cap/cover over the lens or the user is provided with the ability to start/stop the camera recording). This is the simplest way found in the literature to preserve participants' privacy and give them the freedom to operate and control the camera themselves, by turning it on/off (Hoyle et al., 2014). Another study endorsed providing individuals self-managing type 2 diabetes and other comorbidities at home with the same privacy option to turn the camera on or off and prioritise their privacy above the study aims. In this study, all participants with multiple chronic conditions complied with the wearable video-based camera recording during type 2 diabetes self-management at home, however there was some variation of the recording time between participants, as some participants were turning the camera off for some periods of "time out" for personal reasons or due to some privacy concerns encountered by the bystanders (Yin et al., 2018).

2-*Blind vision and secure processing*: The system doesn't know the nature of the processed data. This privacy option will give the opportunity to recognise and automatically process the activity/task needed to be recorded by the camera without any human intervention to filter the activity/task manually.

[1] https://gdpr.eu/what-is-gdpr/

3-*Redaction*: By applying some privacy filters on the captured data which may be alteration privacy filters (blurring or pixelation) or destructive filters which turns the subject into a cartoon (avatar) image.

4-*Data hiding*: This approach encodes the data using crypto methods.

In sum, different concerns about data protection, data accessibility and privacy were noted during the use of the camera systems, particularly when installed at the patients' private homes outside the healthcare settings as it may breach the privacy of other family members without their permissions or capture other intimate daily activities; so, a privacy-aware and acceptable video-based camera interventions are needed (Arning & Ziefle, 2015; Romanou, 2018). Future research will explore the users' privacy concerns while using the video-based wearable camera to support their multimorbidity self-management at home. Climent-Pérez & Flórez-Revuelta's suggested privacy solutions will guide any discussion and agreement with persons with multimorbidity about their privacy issues.

4.2 Behaviour change strategies to reduce privacy concerns surrounding camera-based AAL technologies

Besides technical methods for attenuating the privacy concerns surrounding camera-based AAL technologies, behaviour change strategies may also be of interest. A key theoretical assumption in the future self-continuity literature is that evaluations of past and present selves have important implications for intertemporal choice – i.e., decisions made in the present that have consequences in the future. This assumption has critical relevance for ESR 8's research because the decision to use camera-based AAL technologies can be construed as an intertemporal choice: while the costs of adoption (e.g., invaded privacy) are accrued immediately, the benefits of adoption (e.g., long-term improvements in safety, health, and independence), albeit reasonably larger, typically manifest only in the future. The decision to accept camera-based AAL technologies therefore requires that older adults defer (health) benefits to, and endure (privacy) costs on behalf of, their future selves. Yet, if these future selves are experienced as distant and nebulous, and people have little reason to hold in high regard those outcomes that accrue to strangers (Parfit, 1984), self-discontinuous individuals may be reasonably unwilling to sacrifice their privacy today only for their future selves to reap the corresponding wellbeing benefits.

To the extent that older adults' acceptance of camera-based AAL technologies can be attributed to an underweighting of the immediate costs (which accrue to the present self) and overweighting of the distal benefits (which accrue to the future self) associated with using the technology, a "future-self intervention" may improve acceptance by shifting the balance of this cost-benefit analysis. Specifically, by promoting older adults' continuity to their future selves, the intervention could result in relatively greater decisional weight being placed on the perceived benefits of the technology, and relatively less decisional weight being given to the privacy implications of the technology. This, in turn, could promote older adults' acceptance of camera-based AAL technologies. Thus, ESR 8's future research will examine the impact of a future-self intervention on older adults' acceptance of camera-based AAL technologies. The research will also investigate whether the effect of the future-self intervention on acceptance is mediated by diminished concerns about the privacy implications and enhanced endorsement of the health and wellbeing benefits associated with using camera-based AAL technologies.

The anticipated applied result of the project will thus be a behaviourally informed intervention designed to enhance older adults' acceptance of camera-based AAL technologies. The relatively simple, low-tech, low-cost, and scalable design of Shah et al.'s (2022) future-self intervention means that it is potentially suited to implementation in contexts where older adults might be contemplating usage of camera-based AAL technologies, such as on a website or in conversation with relevant personnel. Furthermore, if results reveal that the intervention increases acceptance specifically by enhancing the vividness and/or positivity with which older adults experience their future selves, results stand to inform the core of future acceptance-promoting strategies that can be tailored to other contexts and technologies.

Several potential ethical implications of this behaviour change endeavour are noteworthy. Notably, there is the ethical consideration of intervening in older adults' decision-making processes surrounding accepting and using camera-based AAL technologies. A future-self intervention designed to promote acceptance of said technology implicitly assumes that such usage will bring about health and independence promoting benefits and this is therefore unequivocally desirable and warranted. Yet, this view negates the diversity of potential users of the technology, some of whom may not reap the same benefits. For instance, while the ageing-in-place benefits of camera-based AAL technologies has been frequently espoused by proponents as a primary impetus for its dissemination, one study found that some older adults prefer to move to nursing homes rather than "stay alone at home […] staring at a wall unable to move" (Sánchez et al., 2019). Arguably, such preferences for or against AAL use must be upheld. However, a point of worthy note is that whilst a future-self intervention may sway older adults in the former direction, such an intervention ultimately preserves older adults' freedom to choose, as the acceptance and/or usage decision is never forced upon the individual and individuals always have the option to choose otherwise. It is important to consider that interventions that infringe upon individual autonomy may be justifiable insofar as these pave the way to welfare-promoting support (Sunstein, 2013). Therefore, to this extent a future-self intervention may promote a decision that is in line with older adults' higher-order desires and goals (e.g., to maximise the welfare of their future, older selves) and such an intervention should be given due credence.

5. Conclusion

In sum, camera-based AAL technologies are scarcely accepted, which warrants research on the effective use of the camera systems and potential strategies to increase acceptance. ESR 7's research has explored the different camera system characteristics and its function application to support home-based multimorbidity self-management. Future research will aim to explore the influence of functional applications of the video-based wearable cameras on technology acceptance as a supportive intervention tool to home based self-management support (SMS) programmes among older adults with multimorbidity. Special interest will be given to the privacy issues associated with technology encountered by the users (older adults with multimorbidity and their care network). ESR 8's research has uncovered that older adults' perceptions of continuity to their future selves has an important influence on their acceptance of camera-based AAL technologies. Thus, targeting self-continuity may be a practicable and powerful strategy to promote acceptance. Future research will aim to develop a theoretically-informed, continuity-enhancing future-self intervention with a view to enhancing the overall acceptability and consequent diffusion of camera-based AAL technologies.

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