

Digital Technology Trends Supporting Assisted Independent Living of Ageing Population

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Abstract. The paper provides a narrative overview of trends in digital technology related innovations for supporting ageing subjects to live independently with assistance, synthesized from selected scoping reviews and informed by subsequent analysis of peer reviewed literature appearing in the past 10 years. Four categories of trends are identified: assistive and supportive technologies; monitoring devices and systems; communications and connection technologies; and intelligent health information systems. For each of these categories, a synthesis commentary and illustrative examples are provided, concluding with a summary discussion on future directions.

Keywords. Ageing, assistive technologies, digital health, health services

Introduction

Technology for supporting ageing well and care provision for ageing subjects has traditionally been seen as providing additional capabilities to those supplied by human carers [1]. Their potential can be realized through consideration of appropriate alignments between technologies, users and care settings [2]. Three major categories of health purpose for this type of technology-based independent living assistance can be distinguished: enabling personal and social interactions; help with daily living activities; and as a means for delivering clinical services [3]. Recently, use of specific digitally-driven technologies to support ageing subjects in various supported situations has become increasingly adopted [4]. Examples of well-established digital technology for ageing subjects include devices to supplement body functions (e.g. hearing, heart function, diabetes medication), systems for monitoring health conditions (e.g. vital signs, physical activities, mental and sleep states), and services for enabling health and wellbeing interactions (e.g. videoconferencing, online health portals, self-care management apps).

The concept of using technology as a channel for implementing new models of care in ageing has been predominantly based on the notion that it is desirable that the care be provided in non-traditional delivery settings, such as the subject's home [5]. This view leads quite naturally to the interpretation of the role of digital technologies in new models of care in ageing as enabling care delivery to be performed remotely (in location and timing), and with the augmentation of remotely collected information and remote interaction and communication mechanisms [6]. For example, it is recognised that remote patient monitoring offers a sound approach for management of chronic diseases [7], and that remote clinician-patient interactions are suitable for a range of specific clinical tasks [8]. It is also acknowledged that various implementation challenges [9] and adoption barriers [10] exist for these approaches.

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1. General Model

There is no apparent standardized nor widely accepted categorization of ageing health-related digital technology areas which can be followed in discussions of associated innovations. Recent literature reviews in the field have tended to aggregate many different application areas rather than conform to a defined structure (e.g. [11], [12]). Attempts to define a universal framework or taxonomy are frustrated by the huge volume and numerous variations in technology types, many having been developed as engineering exercises in non-clinical settings. A recent categorization based on contemporary technology development activities [13] suggested seven clusters: Robotics, General ITC, Sensor technology, Telemedicine, Medication dispenser and Video games. These are somewhat imbalanced for broad scoping purposes, as they vary between highly generic and highly specific topics.

Instead we will align our discussion with four areas of technology usage which are associated with broad types of care purpose, from the perspective of subjects-of-care, and so are distinctive in their orientations of access to or provision of care within the Ageing care ecosystem. These four areas were synthesized initially from a collection of widely-cited scoping reviews and categorization discussions such as those abovementioned. These sources were identified by expert consensus, as an initial step in a more extensive ethnographic analysis of references extracted by structured searching of peer reviewed literature appearing in the past 10 years as reported in detail in [14]. We did not include use of digital technology for business management and non-healthcare operations delivery (e.g. roster scheduling), nor technology used routinely for clinical process support (e.g. patient record systems).

For each of these four areas, we briefly summarize some apparent trends in the recent work related to major use cases, indicative of the overall directions that the field is following. These use cases were chosen due to their high prevalence in literature on ageing and technology and are not necessarily exhaustive, but may be regarded as dominant. We contend that these areas are major “promising directions” in digital technology trends supporting assisted independent living of the ageing population, and can be expected to have a strong impact on the successful implementation of new models of care and health in ageing. The four identified areas are:

- Assistive and supportive technologies which provide physical or cognitive aids to activities undertaken by a subject-of-care as an adjunct component of the activity.
- Monitoring devices and systems which measure and analyze personal health characteristics of a subject.
- Communications/connection technologies allowing a subject-of-care to interact with health carers remotely.
- Intelligent health information systems which empower subjects-of-care to access information and exercise informed control on their health circumstances.

2. Emerging Trends

We next provide commentary on the trends observed for these above four areas, as discerned in our literature survey, including some illustrative examples.

2.1. Assistive and Supportive Technologies

A common need for the elderly is *assistance in mobility* to overcome ambulatory limitations (e.g. wheelchairs). Digital technologies incorporated in mobility devices may be simple such as instrumented canes or frames or may incorporate more sophisticated mechanisms such as motion surfaces, limb supplementation and balance enhancement, depending on the mobility purpose and needs. An important related area is the detection and prevention of falling, which

is often a consequence of compromised mobility and potentially tractable through measurement and prediction. The use of Smartphones for mobility information collection and analysis could offer an easier pathway to delivery. The possibility that routine home care activities could be conducted by an autonomous device such as a robotic assistant has become a popular view, suggesting an appropriate form of generic technology to assist ageing in place.

Decline of *auditory and visual sensory functions* which enable interaction with surroundings cause limitations for older adults, typically addressed through external solutions such as hearing aids. The alternative of internally fitted smart devices such as the cochlear implant is now also established. Progress on augmenting or replicating loss of vision by more sophisticated technology solutions has been slower due to highly challenging neurological mechanisms at the three main sites of intervention: retina, optic nerve and visual cortex. Cognitive decline including loss of memory, balance, location and situational awareness, logical reasoning or understanding of context, through to pathological brain ageing or mental diseases, has been a popular target for technology-based approaches. A range of technology options have been identified, from computer-based sensor-controlled living environments to communication systems enabling involvement of carers in times of need. This approach is sensitive to the specific nature of the cognitive impairment and associated behaviours.

2.2. Monitoring Devices and Systems

Healthy ageing support through digital technology applies measurement and feedback on aspects of healthy lifestyle habits, physiological status, and preventive practices to assist subjects to manage and maintain their condition. This is generally achieved through use of wearable monitoring devices which collect data on variables appropriate to the subject's health circumstances. Other devices can be used to measure physiological quantities or signals which in conjunction with movement information, can allow prediction or detection of adverse circumstances e.g. falling, or cardiac events. A more comprehensive use can be the tracking of performance of conventional daily living activities or the remote observation of individuals by health service providers. Beyond activity tracking, numerous wearable devices for vital signs are also available. It is recognised that there is widespread potential for activity tracking for aged subjects in particular. Future devices may adopt IoT technology enabling greater chance of compatibility and redeployment.

Management of health conditions of individuals (such as chronic diseases) can be conducted outside of clinical environments, using measurement devices located on the subject or in their living spaces which communicate data to a remote clinical decision support system or a clinician. Devices to conduct this telemonitoring function include single and multiple vital signs loggers, heart and brain signal capture, and patient contributed inputs such as alarm buttons. They can also be incorporated into standalone integrated platforms or workstations, which aggregate data locally and provide some limited feedback and analysis to the subject, while communicating and remaining under control of a central clinical agency. The workstation may be used according to a fixed regime (e.g. daily) or when the subject feels it necessary (e.g. if experiencing symptoms). Alternatively multiple devices can be combined in a single portable or wearable system with inbuilt data communication and collection capability, often implemented as body area networks. Incorporation of mobile technologies in this setting offers an easier alternative to integration but is reliant on telecommunications infrastructure. There is argument for a more integrated approach to the future design of such systems to allow for their easier repurposing or extension, for different health conditions.

Ambient Assisted Living (AAL) environments are sensor-equipped and computer-managed living spaces which automatically observe and respond via messages and alerts to health status indicators of their aged and potentially frail or disabled occupants: this concept is also styled as "Health Smart Homes". Target areas for wider application in aged living

include health and environmental monitoring, and providing companionship, social communication and recreation/entertainment. Concerns on ethics of AAL for observing individuals closely and continuously raise issues on privacy and trust, and more generally for user acceptance in health IoT settings. A practical open issue is how large volumes of data generated by such uses can be efficiently and reliably processed by “big data” methodologies.

2.3. Communications/Connection Technologies

In a service environment where person-centred ageing care approaches are becoming more widespread, *telehealth* in various forms offers a natural technology-based mechanism for enabling new model of care solutions. For example, an appraisal of potential expanded usage of telehealth services in UK based on the “Whole Systems Demonstrator” project has suggested that this is a favourable environment for achieving integrated care. Allowing delivery of care by remote clinicians through teleconsultations and teleprocedures is a major component of this area. Another area which has benefited from embracing this approach has been chronic condition management. It has been noted that adoption and acceptance of home telehealth depends on the sensitivity with which the service is delivered, especially regarding the level of support given to subjects and their active involvement. These models also depend on dedicated service elements such as concierge in shared living facilities, or callcentres for broader scale community aged care, and on other appropriate technology solutions which are designed to support users sympathetically with their needs and abilities.

The ability of a computer to substitute for the role of a human is a compelling approach when health tasks are sufficiently simple that human delivery is a waste of resource. A *conversational agent* is a computer program which interacts conversationally (by text or speech) with a subject and is able to satisfy the expectations of the user and the service being delivered: chatbots and avatars are common examples. These have begun to see use in health applications which entail routine human verbal interaction such as self-report observations or medication reminders, with potential in mental health and dementia. Agents for use in satisfying health needs for ageing subjects require particular conversational structures to be effective, and may need to be tuned or adaptive to cater for differences between user preferences and capabilities to ensure effectiveness and acceptability.

2.4. Intelligent Health Information Systems

The trend for *individuals seeking information* about their health condition to make use of Internet sources has accelerated and in general has become an expectation in primary health care where patient-centred activities are preferred. Recently there has been a move to provide websites where information on particular areas of health need (e.g. cancer, diabetes, end-of-life) is aggregated and a compendium of background explanations, guide to clinical; evidence, resources for self-help or group support, and links to external resources are provided. There is a view that the practice by subjects of extending and embedding their knowledge of their health conditions and health histories provides a lifelong mechanism for better engagement, with an implication that ageing individuals who have already developed familiarity with such an approach can benefit from it in their years of declining health. Online sources of information on health conditions can be enhanced with material to support management of conditions and activate patient involvement in their care, and so improve patient outcomes.

Use of technology can provide value in supporting *care delivered in non-clinical settings* which are served by a variety of carers (implied by the last three areas above) in care coordination, telehealth services, and data-driven quality of care monitoring. These aspects of service delivery must be considered in the context of the need for services and the ecosystem which influences their delivery. It has been recognised that using technology to

move the focus of control to the subject can be effective: for example, cooperation by the individual in remote monitoring of chronic disease and behavior change, or in making use of mobile apps to take responsibility for their day to day health care needs.

3. Concluding Discussion

Across the four identified categories there is much commonality in many of the technology components. The use of sensors and wearable devices, and the associated use of smartphones and networked/IoT environments, is a repeated theme. A need exists therefore to ensure that these components can be easily integrated and interconnected, requiring progress in the area of standardization of protocols and data management. Much of the commentary on evolution of new digital technology solutions raises issues related to adoption and compliance, with associated ethical or social imperatives. Development of digital technology solutions in harmony with user expectations and preferences, taking into account limitations on digital literacy and usability for ageing subjects, is essential for creating successful products. While much progress has been made in conventional areas of health informatics such as electronic health record systems, addressing the needs of ageing citizens has generally been less popular. This has been due in part to design challenges across diverse stakeholder groups, and due to adoption reluctance by health services strongly reliant on human-based delivery mechanisms. If digital technology is seen as a means to enable new models of care and improve quality and equity of access, there is potential to accelerate new solution developments in this sector.

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