



Ambient Intelligence Systems for the Elderly: A Privacy Perspective

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Abstract. Over the past few decades the significance of information and communication technologies has become apparent across various sectors of our modern society. In tandem with the global technological revolution and an increasing reliance on technology we have seen changes in the demographic profile of our populations. There is a worldwide trend of an increasing number of elderly people. Technology is seen as one option for supporting the elderly in maintaining social relationships, monitoring their health and living independently. One technological innovation that has been explored in various facets to support the elderly is Ambient Intelligence. This paper discusses the privacy implications of ambient intelligence based systems taking into account elderly users and adopters. Technological advancements and their applications should be understood from a socio-technical basis with regards to the potential impact on users and society at large. This research study adopted the systematic literature review method to identify, analyze and synthesize secondary data. This study appraises existing literature related to Ambient Intelligence, privacy concerns and the elderly over the past decade and contributes lessons and direction for practice and research.

Keywords: Ambient Intelligence · Artificial Intelligence · Assisted living · Senior citizen · Digital inclusion · Systematic review

1 Introduction

1.1 Background

Over the past few decades the significance of information and communication technologies (ICT) has become apparent across various sectors of our modern society. According to [1] the world is in the midst of the fourth industrial revolution (4th IR) which is driven by ICT innovations which will further transform the modus operandi of governments, businesses and society at large. The 4th IR is characterized by a variety of technological developments including artificial intelligence, nanotechnology, robotics, biotechnology, 3-D printing, cloud computing and the internet of things [2]. Recently we have seen scholars also refer to the concept of Society 5.0 which sees the emergence of a super smart society through systems that integrate advanced technologies resulting in a merging of the cyber and physical domains [3].

In tandem with this global technological revolution and an increasing reliance on technology we have seen changes in the demographic profile of our populations. There

is a worldwide trend of an increasing number of elderly people [4]. It is noted that in 2019 there were approximately 703 million people over the age of 65 and this figure is expected to increase at a rapid rate in the coming decades [4]. Life expectancies have increased and as people age they face various health and physical challenges requiring more support to cope with their daily lives. Technology is seen as a viable option for supporting the elderly in maintaining social relationships, monitoring their health and living independently [5–8].

One technological innovation that has been explored in various facets to support the elderly is Ambient Intelligence (AmI) often referred to as Ambient Assisted Living (AAL) systems. AmI is a multi-disciplinary approach underpinned by technology with the aim to enhance the way environments and people interact with each other [9]. AmI brings intelligence into humans' spaces (such as homes or offices) through a network of sensors, intelligent devices and interfaces that are sensitive to the presence and needs of people [10, 38].

Privacy concerns are highlighted as a significant barrier to the uptake of AmI systems in the literature [52]. This paper, based on a systematic literature review (SLR) discusses the privacy perspectives of ambient intelligence based systems taking into account elderly users and adopters. Technological advancements and their applications should be understood from a socio-technical basis thus taking into account the potential impact on users and society at large. The paper is organized as follows: next it considers the informing literature and related works, then the research methodology is explicated. This is followed by a discussion of the results and thereafter conclusions are put forward.

2 Related Work

2.1 Ambient Intelligence Overview

The information society is a key driver behind AmI [14]. AmI is understood to be a digital environment that proactively, intelligently and sensibly supports humans with their daily lives [9]. AmI is ingrained in people's surroundings and responds to their needs so as to empower them [15, 16]. It is a multi-disciplinary concept that is influenced by several research areas including: Artificial Intelligence, Pervasive and Ubiquitous Computing, Sensor Networks as well as Human Computer Interaction (HCI) [9, 17].

AmI can be implemented using a variety of technologies however [17] highlights that AmI systems should display the following features:

1. Sensitive – sense and process data from its environment or users.
2. Responsive – respond to user's requirements and act based on the data.
3. Adaptive – understand the context and change accordingly.
4. Transparent – the technology and computing devices should not be visible and in effect unnoticeable.
5. Ubiquitous – computing devices are everywhere.
6. Intelligent – there must be artificial intelligence to enable the system to be aware, make decisions and adapt to the needs.

In essence AmI systems will sense data from their surroundings, interpret the data, make a decision and act accordingly [17]. AmI based systems have increased and we see their applications in areas such as smart cities, health care and safety, smart public spaces, smart schools, intelligent work places, smart homes, cyber physical systems, smart factories, smart products such as automobiles and manufacturing to highlight a few [9, 10, 14, 17, 18].

2.2 Ambient Intelligence Solutions, Applications and Research

Studies indicate that by 2050 at least one in six people globally will be aged 65 years or older [4]. The application of AmI systems in the context of ageing populations is growing. Examples of how AmI systems may be implemented for the elderly in practice include but are not limited to:

- In the health care sector where an elderly person residing alone may have a smart home that has various sensors and smart devices that can pick up when the person may be in danger and alert emergency services [59].
- For safety in the home such as fall detection capabilities and reminders for daily activities including consumption of medication [52].
- To support social participation e.g. allow for video calls or obtaining information about social events from the system [45]

Scholars and researchers have also sought to understand how the AmI services may assist the elderly taking into account the multi-disciplinary technology and people related aspects of the topic. Topics that have received scholarly attention include: addressing user motivations and technical solutions for AmI in support of ageing in place [19]. Alternatively [20] reviewed AmI and the social integration of the elderly. Additionally, [21] proposed a gerontechnological software architecture for emotion recognition, monitoring and regulation in the elderly. The exploration of an innovative neuro-fuzzy approach to design an adaptive and interoperable emotion aware AmI framework was conducted by [22]. There was also a project targeting the social inclusion of the elderly through AAL [23]. The scholarly perspectives in the literature vary and this study sought to focus on the privacy perspective of AmI systems with an interest in the elderly population. According to [33], the elderly can be considered as a special group in relation to the adoption and use of ICT's.

2.3 Privacy and Information Technology

The notion of privacy may be understood in a number of ways [65]. In the information systems domain the privacy of one's information or data is an individual's ability to control or influence the handling of data about themselves [30, 33]. The authors in [24] highlighted the need to understand privacy issues related to modern ICT's in an increasingly networked world. More recently we note that the rise of smart phone ownership, internet access, ubiquitous and pervasive computing, mobility, wearable technology, cloud computing and the upsurge of cyber threats indicate that technology related privacy considerations are an ongoing area of scholarly interest (see for

example: [25–29, 31, 32]). From a physical and socio-technological context privacy can be considered in terms of [65]:

- Information privacy – the regulations that direct the assembling, storage and management of people’s personal data.
- Bodily privacy – individual’s privacy in terms of their physical bodies.
- Privacy of communications – which concerns the privacy of telephonic, email and other electronic communications.
- Territorial privacy – which may cover aspects such as ensuring privacy for individuals in their workplaces, homes as well as public areas.

Technology innovation brings much needed efficiencies and benefits to society however these should be balanced with the privacy risks [27, 31] posed to individuals such as the elderly. In [31] it is argued that further research on privacy is required. In the context of AmI systems users such as senior citizens are expected to share various personal data for instance location data and medical information such as their blood pressure [40]. Thus privacy of this information is essential. As [41] notes AmI systems should consider several significant non-technical factors such as affordability, legal, policy, regulatory and ethical issues such as privacy.

2.4 Literature Reviews on Ambient Intelligence

Researchers have previously undertaken literature reviews on the topic of AmI. The literature reviews have for example covered AAL technologies, products and services, their usability and accessibility with a focus on user interaction and how end users are incorporated into the AAL development and evaluation processes [34]. In contrast the authors in [35] sought to understand the ethical concerns regarding the research and development, clinical experimentation and application of AAL technologies for people with dementia. With the growth in social networking, the paper by [20] reports on an SLR focusing on how AmI and SNS technologies have been adopted for the social integration of senior citizens. Additionally, [36] aimed to provide a review of the AmI domain including technology solutions and their related challenges. A review of available software tools that end users may use to configure AmI based services for smart homes was conducted by [37]. An SLR on the sustainability of AmI services was completed by [8], who also offered an evaluation framework related to mobile AmI and a method to evaluate sustainability using fuzzy logic. This study appraises the existing literature related to AmI, privacy and the elderly over the past decade to illuminate lessons for practice and research.

3 Research Method

3.1 Systematic Literature Review

This research study adopted the systematic literature review (SLR) method. The SLR incorporates a structured and systematic method to identify, analyze and synthesize secondary data. In [11] the authors highlight that a review of the literature is an

essential element of research and academic endeavors. Literature reviews may form the basis for building new knowledge through analyzing and synthesizing previous work. This study undertook the SLR to obtain insight into potential lessons from the extant literature regarding the proliferation of AmI based systems and their privacy related factors. The SLR process was guided by the recommendations of [11–13].

Research Questions

The paper addresses the following research questions:

- *Which privacy concerns are reported in the literature regarding Ambient Intelligence for the elderly?*
- *What privacy protection approaches are recommended in the literature regarding Ambient Intelligence for the elderly?*

Data Sources and Search Strategy

Four academic databases were included in the search for relevant literature. These were databases that were deemed to include high quality, peer reviewed conference and journal papers in relation to the scope of the paper:

- Scopus
- Association for Information Systems (AIS) eLibrary
- Association for Computing Machinery(ACM) Digital Library
- EBSCOHost - Academic Search Complete

The following search string was adopted:

“elderly” OR “older” OR “senior” AND “privacy” OR “data privacy” AND “ambient intelligence” OR “ambient assisted” OR “ambient assistance” OR “ambient assisted living”

Inclusion and Exclusion Criteria

The inclusion criteria that were defined and stipulated for the identification of articles were as follows:

- Peer reviewed journal articles or conference papers.
- Articles that address AmI in the context of elderly users.
- Articles that explicitly discuss the privacy aspects regarding the AmI related solutions.
- Articles published during the period 2009 – 2019 to allow for recent perspectives from scholars.

The exclusion criteria were stipulated as follows:

- Articles that are not written in English, are inaccessible or are published outside the stipulated timeframe.
- Articles that are not focused on the elderly population (60 years or older).
- Articles that do not discuss any privacy or ethical topics related to AmI use by the elderly.

Search Results

The papers that were sourced were managed through the EndNote X9 reference manager tool. The initial search process yielded results from the various database sources and are highlighted in the following table (Table 1):

Table 1. SLR search results

Database	Number of papers returned
Scopus	99
AIS E-Library	26
ACM digital library	566
EBSCOHost	8
TOTAL	699

The following figure outlines the process for identifying qualifying papers from the search results for inclusion in the final analysis (Fig. 1).

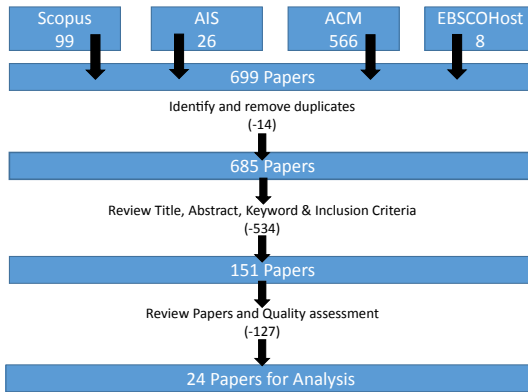


Fig. 1. Identifying papers for analysis.

3.2 Data Analysis

A thematic analysis was conducted to identify themes emanating from the papers. The overarching themes were linked to the objectives of the paper which were to identify privacy concerns and privacy protection strategies in the papers.

4 Findings and Discussion

4.1 Overview of the Papers

A total of 24 papers were included in the analysis. The following section provides an overview of the papers included for analysis. The figure below highlights the distribution of papers over the time period of interest which was from 2009–2019 (Fig. 2).

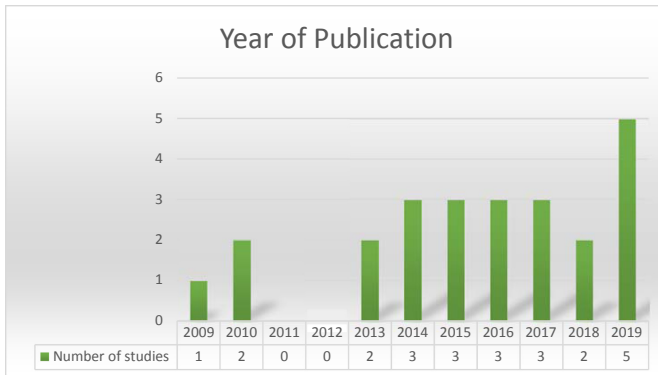


Fig. 2. Publication by year.

The figure below highlights the research design adopted in the papers. This included surveys, case study and experiments (Fig. 3).



Fig. 3. Publication research design.

4.2 AmI Privacy Concerns and Privacy Protection Approaches

As argued by [35] privacy is an important matter as it relates to AmI based systems. The papers that were included for analysis addressed a myriad of privacy related concerns touching on both technical and human aspects. The following section addresses the research question: Which privacy concerns and privacy protection approaches regarding AmI for the elderly are noted in the literature?

Privacy Concerns

The reported privacy concerns highlighted in the analysis of the data are:

- Senior citizens are concerned with who has access to their data and if they are able to manage the access to their data [56]. Also of concern is the risk of third parties having access to their data without their knowledge [52] coupled with the informed consent of elderly users [55]. This is further linked to the need for protection from the disclosure of sensitive or harmful information [56].
- Elderly users of AmI systems are concerned about their data being misused [45] and the appropriate sharing of data [60].
- Also of concern is how the elderly can have a say and control with regards to how the data that has been collected is used by collectors (e.g. AmI providers or health practitioners) [40]. This control over their data is an important consideration [41, 44]. AmI systems are often everywhere and constantly collecting data making control over data and the purpose for which the data is used difficult for the elderly [41].
- The risk of being under constant surveillance is worrying to some elderly adopters of AmI [45] and the authors in [46] highlight the threat of what they term “dataveillance”.
- An additional concern that comes with the loss of privacy due to ongoing surveillance is how this may affect the elderly e.g. it may cause some individuals to feel stigmatized or have a sense of losing their independence, dignity and freedom even in their own homes [43, 49]. The impact of such systems on the elderly must be understood and balanced with the need for the service e.g. a health monitoring or safety service.

Privacy Protection Approaches

The literature highlighted the following for consideration towards enhancing the privacy of the elderly throughout the use of AmI systems:

- When compiling AmI services consider why the elderly seek privacy since there may be different requirements and needs for privacy depending on individuals and these should inform AmI systems [56].
- AmI services organizations are encouraged to have an architecture comprising of a myriad of privacy related policies informing different domains such as privacy policies covering the ubiquitous environment, privacy policies covering the user, policies concerning the devices and policies addressing communications e.g. public key certificates [41, 60].

- One approach to enhance privacy is through minimizing information asymmetry in the context of AmI by increasing information flows from the data collector and users. Where the elderly are not able to use the information it is recommended that family members may act as proxies to support the elderly [40].
- From a design, development and implementation perspective companies should consider raising the awareness of developers and engineers on the ethical and privacy implications of their solutions such that these are taken into consideration [39]. Additionally documenting privacy based guidelines to inform product development is noted. Designers and developers may seem far removed from the elderly users however it is purported that building solutions that take the values of privacy into account may contribute positively. This can be achieved through a “privacy by design” approach where designers, developers and legal expertise collaborate to enhance privacy [41, 60].
- AmI services must be framed within the relevant technical standards and legal statutes. There should also be a consideration of conducting privacy impact assessments [60] to identify potential areas of concern before implementation.
- Rather than collecting and transferring a vast array of data AmI solutions may consider limiting the data collected and transmitted to only what is essential and necessary to deliver a service [42]. So the intention for accessing particular types of data is a central guiding principle [59]. For example, if an elderly person is at risk of falling due to health related constraints, only data that is related to this aspect should be collected to support the senior citizen’s privacy. Another example is to avoid capturing visual data (e.g. data collected via cameras) [61] but if visual data is needed then organizations should place a limitation on what is collected and stored by making modifications that enhance individuals’ privacy [48].
- With the growth of the AAL industry and AmI services, employees in this sector should also be trained in ethical issues spanning data protection and security, privacy and user monitoring limitations and where possible a specific job role geared to ethics should be included in the organizational structure of the AAL service providers [47].
- Additional technology related strategies were noted from the literature such as: consideration of a suite of privacy enhancing technologies, the use of authentication protocols [50], proxy based authentication [57], cryptography and related security tools and methods [51, 53], also consider technology that is non-invasive [58] and has privacy preserving features [54].

4.3 Privacy Implications of AmI for the Elderly

It is noted that as the adoption of technology increases, the concerns regarding personal information privacy in the digital era also grows [62]. Scholarly research related to privacy is on the rise across the engineering, social science and computer science domains [62]. The elderly are increasingly reliant on technologies such as AmI for assistance with daily living, their safety and health. Due to the potential significance of the AmI services for the elderly they can be more vulnerable since it may be argued that the decision to not use the technologies may not be an easy one. Thus enhancing their privacy as related to AmI services remains a pertinent discussion.

One potential approach that may be elevated is the de-identification of the elderly users' data. The potential of further exploiting the de-identification of data for the context of AmI requires additional probing. AmI may enable privacy invasion since it allows for the collection, transfer and storage of various information including personal identifiers [65]. De-identification outlines a process of taking away personally identifiable information to protect individuals [67]. De-identification does however allow for relevant stakeholders to extract identifiers if required which may link the information to an individual [65]. Various types of de-identification may be relevant for AmI solutions such as: gender, age, race de-identification, or scars, marks and tattoo de-identification, also face, voice, gait and gesture de-identification as a few examples. De-identification albeit a recommended approach requires the collaboration of social scientists and technology experts to address social, political and the legal implications of de-identification [65].

Additionally, the issue of privacy needs to move beyond a technical focus. One proposal is that privacy laws, regulations and technology must be understood from different perspectives such as people, processes, technology and information dimensions [66]. This may enable a holistic approach to addressing privacy concerns for innovations such as AmI.

It is also proposed that opportunities for enhancing privacy from the perspective of the end user are considered. This may include training and awareness initiatives for the elderly regarding the options available to improve privacy and how to protect themselves while using a particular AmI solution. The elderly may require additional support when using technologies [63]. Technology based services should include training on how they may be used effectively [63] and the AmI specific training should include ways to enhance one's personal privacy. This training should ideally consider how older adults learn and include methods such as adaptive learning approaches [63]. It is also essential to consider both system and user aspects in the learning approaches [64] to favor the elderly. AmI providers may consider incorporating additional and easily accessible support channels for elderly users who may have concerns for their privacy.

5 Conclusion

5.1 Concluding Remarks

This paper reported on a systematic literature review that appraised the current literature on Ambient Intelligence to understand the privacy issues highlighted by scholars in relation to the elderly. The paper presented the privacy concerns and followed with potential strategies and approaches for enhancing privacy protection. Twenty four (24) primary sources were analyzed to address the research questions. The discussion adopted a socio-technical view elevating both the technical and people related privacy considerations captured in the literature. The results show that although AmI based solutions hold potential for the elderly, the benefits should be considered in tandem with the risk of privacy intrusion.

5.2 Contribution, Limitations and Future Research

This study contributes through bringing together several privacy related concerns pertaining to AmI for the elderly as published in the literature over the past decade. All research studies have limitations and this study was limited to data from four academic databases with regards to the search for articles. Future studies may consider extending the search to additional databases. Scholars and researchers may consider adding to the current knowledge on AmI and privacy for the elderly by tackling human aspects that appreciate that the elderly are not a homogenous group. Thus future research should investigate how different groups within the elderly population perceive privacy concerns. For instance different privacy attitudes may be held by various senior citizens influencing their requirements of AmI systems.

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