Barriers and Facilitators of Ambient-Assisted Living Systems: A Systematic Literature Review (Study protocol)

Contents

1 Background

AALSs are a set of technologies whose main objective is to increase the time that people can live autonomously [5]. Such systems are primarily aimed at older adults, disabled people or caregivers, with the idea that they can be extrapolated to other social groups, such as people with functional diversity. The technologies, programs and applications that encompass AALSs have to be able to collect data but also monitor (and try to correct, as far as possible) the life habits of the users [2].

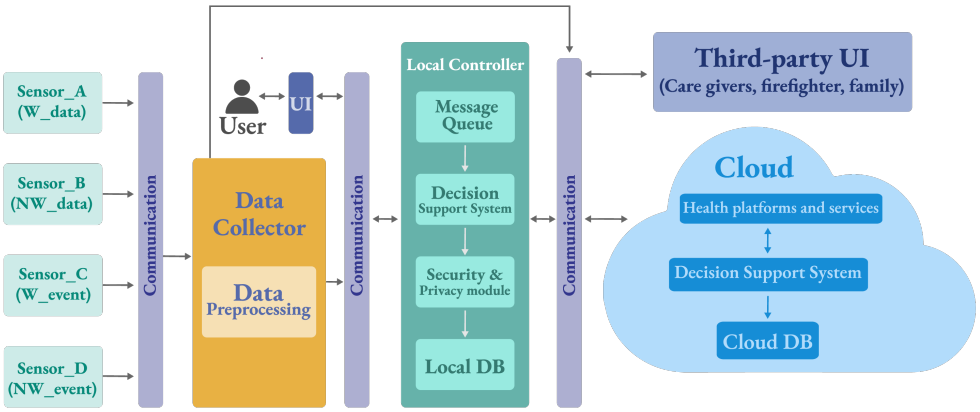

Figure 1: Architecture of an AALSs adapted from [9]

AALSs use devices to help older people and disabled people clean, cook, shop, take care of hygiene, diet and monitor medication and health care. Beyond support for housework and personal care, these devices have also helped to prevent injuries at home and alert support services in case of a fall; to facilitate people's mobility and ensure that they can move around on their own; or to foster their social integration and reduce feelings of loneliness and isolation [13]. The technologies used in AALSs have been designed to enable the elderly and people with functional diversity to live independently, helping them perform everyday tasks that they usually cannot act on their own. In this way, an environment is created in which people can continue to be self-sufficient citizens.

Figure 1 describes the basic architecture of an AALSs. Both sensors and medical devices act as inputs to the system, which, through a communication channel, send their data to a component whose functionality is to collect the obtained data. In this component, pre-processing algorithms are executed that clean, load, and transform the data obtained from the sources in order to obtain structured and ordered data. Using another

communication channel, the data can be sent to a component that manages the data in order to be prepared for the end users. In parallel, it is possible to visualize the data that have already been processed using the same communication channel. Finally, once the data is managed, it can be sent to different end points for different purposes. These purposes can be the visualization of patients by relatives and care centers or storage in the cloud.

1.1 Related work

Sun et al. [12] discuss current issues regarding the development of AAL systems for older people. The authors describe that efforts to build home care environments are many, but significant challenges need to be addressed. For example, one of the challenges identified is the potential for social isolation due to the overuse of technology and the lack of communication between the assisted persons and the outside community. On the other hand, the authors identify that governments are making more effort to establish social connections between assisted persons and the outside world.

Garcés et al. [6] describe models and quality attributes related to AALSs. The authors identify the main quality attributes that identify AALSs, how the attributes were defined and assessed and the subdomains of AALSs where they were proposed. The results of this study point to the fact that there is still a need for greater industry involvement in the engineering of AALSs to primarily establish quality management and its associated quality assurance, which could be considered essential for any AALS system.

Abtoy et al. [1] discuss the concepts of reference models and reference architectures for designing AALS. The authors describe different architectural styles in order to summarise the weaknesses of each of them. In turn, the authors propose a set of dimensions and classifications in order to highlight the main areas that need to be addressed by AALSs. The authors highlight the need for ease, interoperability and independence to be present in AALSs.

Choukou et al. [3] conduct a systematic review of the literature aimed at scoping and reporting on advances in AALSs in terms of health outcomes in older adults. The authors describe that AALSs have made a significant contribution in terms of patient quality of life. However, they also mention that there is insufficient empirical evidence regarding AALS and patient care.

Dimitrievski et al. [5] mention that current research on AALSs lacks sufficient experimental results with data from continuous monitoring. In turn, the authors describe that AALSs is a field that has the potential to benefit from machine learning based on the data that is processed by devices and sensors. In turn, the authors mention that in order to create a supportive environment that does not stigmatize older people, the focus should be on collecting data from non-intrusive environmental sensors.

Jovanovic et al. [7] conduct a review of the literature on artificial intelligence models in AALSs. The authors discuss specific artificial intelligence models that are widely used in AALSs. In turn, the authors focus on articulating the research toward end-users, healthcare professionals, researchers and practitioners in the development of intelligent AALSs.

Cicirelli et al. [4] analyze the AALSs literature from the point of view of existing contexts, technologies and approaches to characterize AALSs development needs. The authors' comprehensive study focuses on AALSs contexts, potential users and functionalities, as well as the technologies and methodologies used for AALSs development and deployment.

The studies described in this section make significant contributions to the line of research related to AALSs. There are different alternatives to how AALSs contribute to improving older adult patients' and disabled people's quality of life. However, to the best of our knowledge, related work has been limited in discussing benefits and challenges that AALSs present in real-world and operational settings. Therefore, our study aims to address this need for more knowledge by focusing the systematic review on a more practical discussion of using AALSs based on facilitators and barriers.

2 Systematic study process

Our study aims to identify and describe the main operational and technical barriers and facilitators of AALSs in order to provide a body of knowledge to derive new solutions and guidelines for implementing and using AALSs. We used the PRISMA methodology [10] to identify and select primary studies based on three steps: identification, screening and included. The main feature of PRISMA is that it provides items that allow reporting on literature reviews in order to perform data analysis and meta-analysis. Therefore, the research questions are as follows:

Research question 1
Which are the main operational barriers to AALSs?

Research question 2
Which are the main operational facilitators to AALSs?

Figure 2 illustrates the PRISMA method for obtaining the studies in our study.

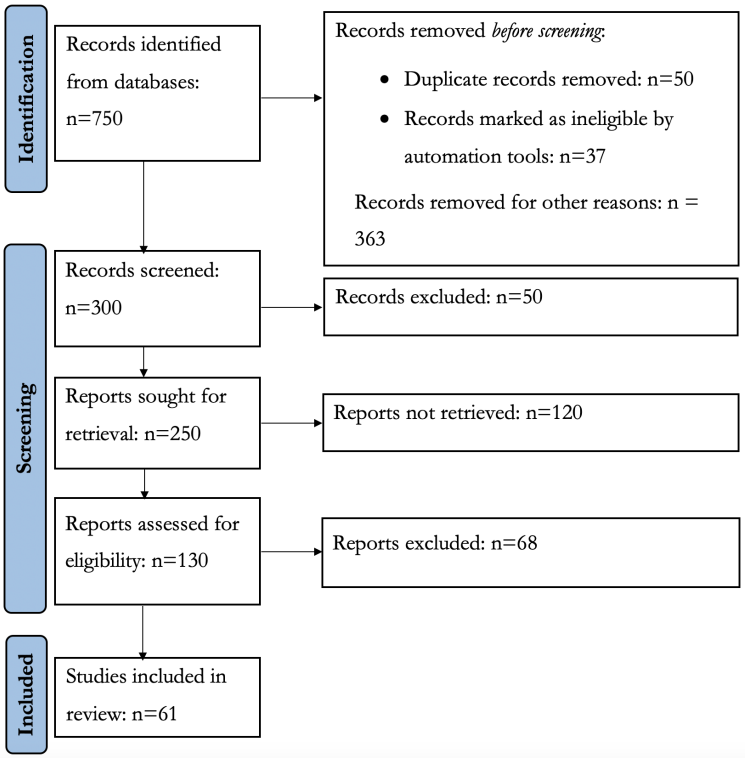

Figure 2: PRISMA flowchart of primary studies selection

2.1 Identification

In this step, we identified the keywords based on the population, intervention, comparison and output approaches [11] (see Table 1) in order to define a search string according to the objective of our research With regard to comparison, this approach is not possible to apply because there are no previous studies on our goal that could serve as a basis for comparison. Subsequently, we join the identified keywords using the "AND" and "OR" operators in order to obtain the search string. With the search string created, we proceed to search for primary studies in the following databases: Web of Science[1], PubMed[2], ACM Digital Library[3] , ScienceDirect[4], IEEE Xplorer[5] and Wiley[6]. The identification process was conducted between January and October 2022. This process involved the study's principal researchers and two collaborators, which are health professionals with knowledge of caring for the elderly and people with disabilities. Through collaborative work, we discussed each piece of information extracted from the primary studies based on the views. In this way, we were able to refine the results of our study and thus decrease the bias in the results.

For each database consulted, the search string must be adapted to the database format. For example, Figures 3 and 4 illustrate how the search string varies between PubMed and ACM Digital Library databases. On the other hand, in some databases, such as IEEE Xplorer, ScienceDirect, Wiley and WoS, the search string is split into sub-search strings as the databases cannot support a long search string. Once the sets of papers obtained by each sub-search string are executed, the results are concatenated and duplicates are removed.

2.2 Screening

We analyzed and refined the primary studies through inclusion and exclusion criteria. Both criteria are described as follows:

- Inclusion criteria

[1]https://clarivate.com/webofsciencegroup
[2]https://pubmed.ncbi.nlm.nih.gov
[3]https://dl.acm.org
[4]https://www.sciencedirect.com
[5]https://ieeexplore.ieee.org/Xplore/home.jsp
[6]https://onlinelibrary.wiley.com

Table 1: Description of the search string

Approach	Description	Keywords
Population	Papers related to AALSs and their derivatives	"ambient-assited" OR "ambient assisted" OR "living"
	Paper related to the types of technologies that support AALSs	"system*" OR "platform" OR "application" OR "software" OR "technology"
Intervention	Papers related to health and care	"health" OR "care" OR "health care"
Output	Data regarding facilitators and barriers	"barrier" OR "disadvantage" OR "pitfall" OR "pain" OR "facilitator" OR "advantage" OR "gain" OR "benefit"

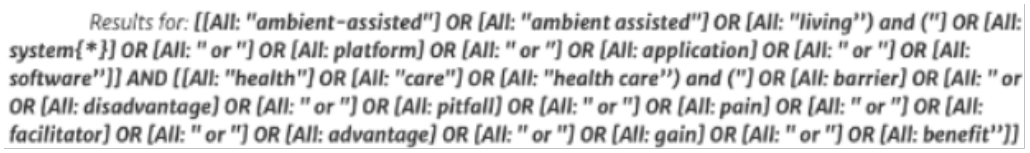

Figure 3: ACM Digital Library search string

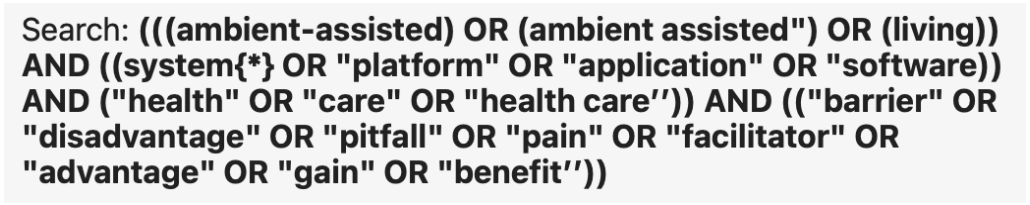

Figure 4: PubMed search string

  - Papers must be related to health and AALSs.
  - Papers must be able to describe the results of their studies explicitly.
  - Papers must detail technological aspects of AALSs.
  - Papers discuss the advantages or disadvantages of AALSs.
  - Papers report, as far as possible, the experience of using AALSs.
- Exclusion criteria
  - The paper does not detail technical or methodological aspects of AALSs.
  - There is no evidence of the advantages or disadvantages of AALSs.
  - The paper does not describe the results of your research.
  - The paper is less than four pages long.

Regarding the inclusion criteria, each paper is critically analyzed using the PRISMA methodology checklist. Each paper was examined focusing mainly on the analysis of the introduction, proposed methods, reported results, discussion and additional information of the paper. The checklist [10] is described as follows:

- Introduction:
  - Rationale: Describe the rationale for the review in the context of existing knowledge
  - Objectives: Provide an explicit statement of the objective(s) or question(s) the review addresses.
- Methods:
  - Eligibility criteria: Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.
  - Information sources: Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.
  - Search strategy: Present the full search strategies for all databases, registers and websites, including any filters and limits used.

- Selection process: Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.
- Data collection process: Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.
- Data items:
  - List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.
  - List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.
- Study risk of bias assessment: Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.
- Effect measures: Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.
- Synthesis methods:
  - Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis.
  - Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.
  - Describe any methods used to tabulate or visually display results of individual studies and syntheses.
  - Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.
  - Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).
  - Describe any sensitivity analyses conducted to assess robustness of the synthesized results.
- Reporting bias assessment: Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).
- Certainty assessment: Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.

- Results:
  - Study selection:
    - Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.
    - Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.
  - Study characteristics: Cite each included study and present its characteristics.
  - Risk of bias in studies: Present assessments of risk of bias for each included study.
  - Results of individual studies: For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.
  - Results of syntheses:
    - For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.
    - Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.
    - Present results of all investigations of possible causes of heterogeneity among study results.

    - * Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.
  - Reporting biases: Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.
  - Certainty of evidence: Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.

- Discussion:
  - Provide a general interpretation of the results in the context of other evidence.
  - Discuss any limitations of the evidence included in the review.
  - Discuss any limitations of the review processes used.
  - Discuss implications of the results for practice, policy, and future research.

Each item on the checklist is evaluated with "yes" or "no". In turn, each evaluation team member evaluates the studies on his or her own. Once the evaluation is completed, the results are compared, and those evaluations where there is a discrepancy are discussed.

To explore more primary studies, we executed a snowballing method [14]. This method is a non-probabilistic (non-random) sampling used when the information in the samples (primary studies) is difficult to find. The main characteristic of snowballing is the use of initial primary studies to generate additional studies. For this study, we used this method in order to increase the search scope for primary studies. We performed backward and forward snowballing procedures (i.e. references and citations), using Google Scholar[7].

2.3 Included

In this step, we obtain the final set of primary studies. In order to organize the information, we created a template (see Table 2) to detail each primary study. The items described in Table 2 allow us to characterize the most relevant aspects of the primary studies. This template allows us to describe demographic data as well as descriptive data on barriers and facilitators.

Table 2: Description of the template used to characterize primary studies

Data item	Description
ID	This item describes a specific identification for each primary study
Name	Name of the study
Authors(s)	List of authors of the study
Year	Year of study publication
Venue	Description of where the study was published or presented
Facilitator	List of the facilitators described in the study
Barrier	List of barriers described in the study

To reduce bias, one author performed the data extraction and the second author verified the information extracted from each paper. Additionally, we classified the primary studies based on the system views proposed by Krutchen [8] (see Figure 5). The views are described as follows:

- *Logical view*: Describes the functionality that the system provides to end users. It represents what the system is supposed to do and the functions and services it offers.
- *Development view*: Details the system from a programming perspective and deals with the management of the software, i.e., it shows how the software system is divided into components and the dependencies between those components.
- *Process view*: Describes the processes in the system and how these processes communicate. Also, it represents, from a system integrator's perspective, the step-by-step business and operational workflow of the components that make up the system.
- *Physical view*: Shows from a systems perspective all the physical components of the system, as well as the physical connections between those components that integrate the solution (including services).

Since the logical view is related to the functionality of the system, we do not consider it for the classification of the primary studies. Nevertheless, the other views allow us to identify and describe the main barriers and facilitators based on different dimensions (development, process and physical).

[7]https://scholar.google.com

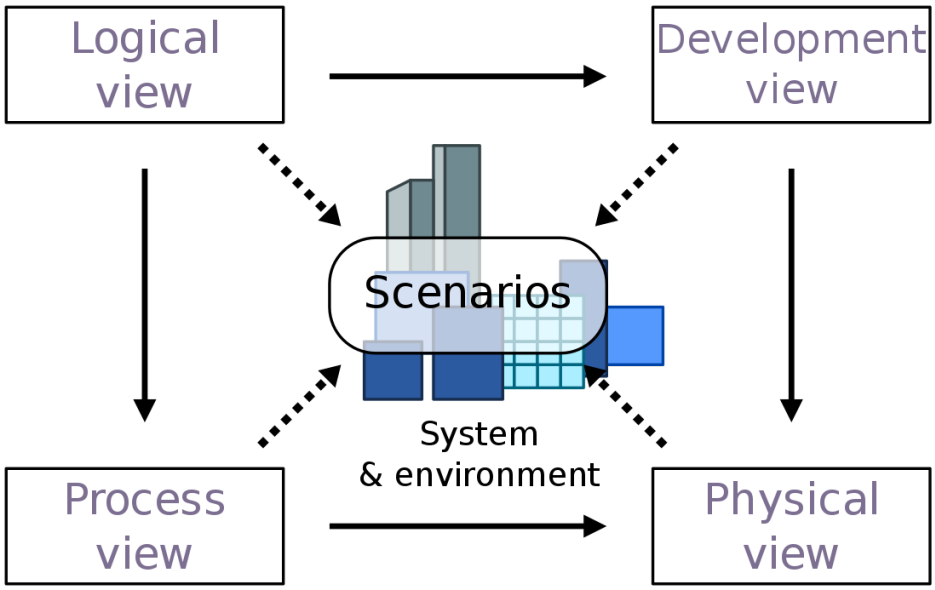

Figure 5: 4+1 architectural view model

3 Dissemination of results

In this section, we describe our plan for the publication of the results.

- The main results will be published in a journal (WoS, Q1) specialized in software.
- We will publish a repository where we will describe the review protocol and the results obtained in order to promote the replication of our study.
- Depending on the results, we will describe the results in practitioner-oriented and health venues in the industry.

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