Are Active and Assisted Living applications addressing the main acceptance concerns of their beneficiaries? Preliminary insights from a scoping review

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ABSTRACT

Active and Assisted Living (AAL) technologies stand as a promising mean to respond to the big societal challenges related to health and social care. Nevertheless, despite their great potential and the recent boost ensured by the advances in Artificial Intelligence for data processing, the uptake in real-life settings of AAL technologies is still in its infancy. Several concerns seem to hinder the willingness of the targeted beneficiaries to integrate such technologies in their routines and living settings. Some studies and surveys have tried so far to identify and analyze these concerns and the factors that affect the immediate acceptance and long-term usage of AAL technologies, thus identifying accessibility, usability, privacy, safety, security and reliability as the core ones. Nevertheless, no attempts have been done yet to verify the reception of these analyses from a technological and implementation standpoint. This paper fills this gap by reporting the preliminary results of a scoping review of the AAL literature. The review investigates the solutions developed in the last five years that address various groups of beneficiaries and their concerns with respect to technology adoption. The results obtained aim to aid researchers, social and health care professionals, end users and technology providers understand the state of play of technological solutions, evaluation studies and the overall discussions that are appearing in the literature to address and respond to the end-users' concerns.

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CCS CONCEPTS

• **Human-centered computing**; • **Computing methodologies**; • **Artificial Intelligence**; • **Security and privacy**; • **Privacy protections**;

KEYWORDS

Active and Assisted Living, End-users' concerns, Privacy preservation, User Acceptance, Accessibility and Usability, Reliability, Trustworthy AAL Technologies, Scoping Review

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1 INTRODUCTION

The demographic change and the critical economic context, further exacerbated by the recent COVID-19 pandemic, are making more and more urgent the call for more effective and sustainable health and social care services.

Active and Assisted Living (AAL) technologies stand as promising instruments to respond to this call, thanks to the high potential they hold in enabling remote care and assistance, via supportive and inclusive environments and applications empowering people in need [1]. AAL capitalizes on the growing pervasiveness and effectiveness of sensing and computing facilities to supply the assisted persons with smart support, thus responding to their needs of health and wellbeing, autonomy, independence, comfort, security and safety [2]. In this respect, a plethora of AAL applications has appeared in the last decades to address heterogeneous scenarios and the demands of diverse beneficiary end users. Some examples include [3]:

- enabling the sustained wellbeing, quality of life and safety of ageing, frail or impaired people
- alleviating the burden of chronic diseases, via continuous and remote monitoring of psycho-physical signs of chronic patients
- supporting at-home physical and cognitive rehabilitation
- preventing the ageing and impaired community from social isolation
- supporting and relieving the burden of formal and informal caregivers
- promoting better and healthier lifestyles for at-risk subjects
- enacting disease prevention strategies based on personalized risk assessment and continuous observation.

The ultimate effect of all the above scenarios is empowering more sustainable health, care and social services, by reducing the pressure on formal health and care infrastructures thanks to remote monitoring, tele-assistance and smart environment facilities. AAL addresses the care and assistance needs of diverse beneficiaries. Usually, the main target users are frail or impaired individuals, chronic and multi-morbidity patients, and ageing healthy subjects. Nevertheless, beneficiaries also include formal and informal caregivers, as the assistive applications can alleviate their work and burden, as well as clinicians and General Practitioners, with the provision of information and analyses of physical, cognitive and behavioral information of chronic patients recorded remotely.

Notwithstanding the diverse application scenarios and beneficiaries, AAL technologies share some common characteristics, as they aim to provide support in daily life in a transparent, unobtrusive and user-friendly manner. Moreover, they feature intelligent functionalities to learn and adapt to the requirements of the assisted people, by synchronizing with their specific needs [4]. Despite their expected smart capabilities and the recent technological boost ensured by the advances in Artificial Intelligence (AI), the uptake in real-life settings of these technologies is still in its infancy and several factors seem to hinder the willingness of the targeted recipients to integrate them in their living settings [5]. In this respect, a multidisciplinary debate among experts and stakeholders has started to better focalize the hindrances to their adoption [6–8]. The classical usability analyses have demonstrated to fall short when considering the eventual acceptance and adoption of AAL technologies by the diverse beneficiary users. The need to take into account other individual concerns, such as trust in technology, data security and privacy, has lately become evident [9]. Moreover, the scientific community, policy makers and funding bodies have started discussing the ethical implications of their use, heading towards the release of guidelines for AAL based on *ethical excellence*, as those promoted by the European AAL Program [10]. New research endeavors have started to focus on the design and delivery of AAL technological solutions able to address a wide range of end-users' concerns, such as ergonomics, usability, reliability, acceptability and privacy preservation. The European AAL Programme DIANA[1] and PAAL[2] projects, the H2020 Marie Skłodowska-Curie action VisuAAL[3] and the Cost Action GoodBrother[4] are some examples of this emerging trend in AAL research.

Starting from the above considerations, the goal of this study is to investigate the AAL solutions developed in the last five years to address various groups of beneficiaries and their concerns with respect to the adoption of AAL technologies. The idea is to identify, from a scoping review perspective, the state of play of the technological solutions, the evaluation studies and the overall discussions that are appearing in the literature to address and respond to the end-users' concerns.

1.1 Scope of the study

Although some studies and surveys have tried to identify and analyze the factors that affect the immediate acceptance and long-term usage of AAL technologies, especially for the older-adults [11–13] and caregivers [14] target groups, no attempts have been done yet to verify the reception of these analyses from a technological and implementation standpoint. This paper investigates the AAL-related literature to identify the emergent solutions and debates to address target-users' concerns. In this respect, the scoped analysis focuses on the following research question (RQ):

> **RQ: What are the significant concerns that have been taken into account when designing, developing and presenting AAL applications or systems?** Starting from the analyses of ethical, social and technological issues identified as critical factors for the uptake of AAL technology [9, 12, 15], we analyze the concerns considered in the retrieved studies as well as the target groups that are therein addressed and assisted.

The time frame considered is the period 2016-2021, to better understand the emerging trends and because previous to 2016 the appearance of papers considering beneficiaries' concerns was very low and sporadic. The findings are intended for researchers, social and health care professionals, end users and technology providers when developing, deploying and evaluating AAL applications. The work aims to identify positive sides of the current technological advances, but also existing gaps in research and practice to provide implications for future AAL applications.

The reminder of the paper is structured as follows: Section 2 describes the methodology of the scoped literature review; Section 3 introduces the results of the analysis of the n=63 finally selected papers and briefly overviews them with respect to the RQ; Section 4 outlines the conclusions, limitations and future development of the survey work.

2 METHODS

The paper has been organized as a scoping review, thus including the analysis and synthesis of the existing literature towards a conceptual framework that systematizes and clarifies the phenomenon under analysis, which is, in this case, the consideration of end-users' concerns in AAL technologies. We conducted a systematic literature search, by using an NLP toolkit developed by some of

[1] http://www.diana-project.eu/ accessed May 2022
[2] https://paal-project.eu/ accessed May 2022
[3] https://www.visuaal-itn.eu/ accessed May 2022
[4] https://goodbrother.eu/ accessed May 2022

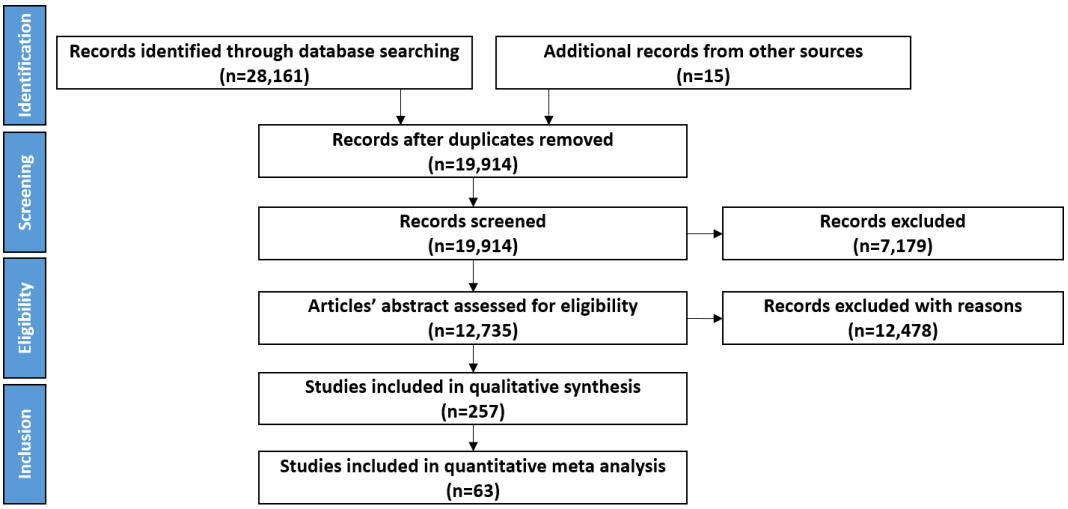

Figure 1: The PRISMA flow of the review process, which encompasses the identification, screening, eligibility and inclusion phases

the authors for automated literature search, screening and analysis [16]. The digital libraries queried included the IEEE, PubMed, Springer, Elsevier and MDPI research-article databases. The study implemented the PRISMA workflow for systematic reviews [17], as illustrated in Figure 1. As planned in such a framework, additional sources were added as the result of a manual search done on the ACM digital library, as this could not be included in the automatic NLP-based search due to technical problems. The relevant papers retrieved this way were added to the original group of retrieved papers.

During the *paper identification phase*, the titles, abstracts and keywords of the papers included in the digital libraries were queried with the search terms reported in Table 1. All the keywords were mandatory, which means that at least one entry of the various groups should have been matched by the results. The NLP-based toolkit used for the automated search accepts a collection of keywords as an input to retrieve potentially relevant papers, combined with the set of properties (or categories) and property groups (as sub-categories) to be satisfied by them. The input can be expanded with keywords and properties' synonyms to fine-tune the search and screening process. Further details on the tool can be found in [16].

The literature search was accomplished in-between January and March 2022 and it included research papers published between 2016 and 2021. The idea was to cover the most recent results, given the rapid advancements in this field.

Afterwards, in the screening phase, the retrieved articles were evaluated to assess their relevance to the RQ. Therefore, the independent inclusion criteria mainly consisted in including papers describing: (a) AAL applications, methods and approaches and (b) end-users' concerns regarding the described AAL application and the potential solution. As exclusion criteria, the out-of-scope condition with respect to the RQ was applied.

The first three authors manually screened the content of each paper independently and indicated its relevance with respect to the inclusion criteria. The papers included were then crosschecked, resolved and confirmed during regular discussions among the authors. Finally, a manual, thematic analysis of the extracted information was carried out as the last step to categorize the solutions considering the various concerns and their beneficiaries. The goal of the analysis was to identify and elaborate whether and how the various concerns and end-users categories are addressed in the most recent AAL applications.

3 RESULTS

The following sections describe the resulting figures of the survey and illustrate the analyses done, herein reported as overall statistics and systematization of methodological approaches.

3.1 Screening process and number of articles

The NLP search toolkit initially retrieved 28,161 potentially relevant papers (Figure 1), which were reduced to 19,914 once duplicates were discarded. The automated screening process further removed 7,179 articles published before 2016 or due to parsing errors in the title and/or abstract, or due to other reasons. Afterwards, the NLP toolkit's advanced functions assessed the eligibility of the remaining 12,735 papers and kept 257 articles (12,478 were excluded with reasons). Fifteen papers resulting from the manual search on the ACM digital library were added to these. This set of papers was then analyzed in detail during the inclusion phase, according to the inclusion and exclusion criteria. As a result, 63 articles were deemed eligible and included in the in-depth manual investigation. This aimed to identify and articulate the research results and trends with respect to end-users' concerns. The results of this analysis are reported in the following sections as a preliminary discussion on statistic and methodological aspects, due to the page-limit and will be followed by more comprehensive and throughout analyses.

Table 1: Key terms used for the scoping review's NLP search toolkit and the manual search

Category	Criteria	Keywords	
AAL	Mandatory	"Ambient assisted living", "ambient-assisted living", "assisted living", AAL	
Beneficiaries	Mandatory	"Older adult", elderly, "Older user", "Older person", "Older people", Ageing, Aging, "Senior citizen", "Senior people"	
		"Frail person", "Frail individual", Frail, Impaired, Impairment, "Disabled people", "Disabled persons", "People with disability", Frailty, Vulnerable, Disadvantaged	
		Patient, "Medical patients", Disease, "Medical condition"	
		"Healthcare staff", Doctor, Clinicians, Physicians, Therapists, "General practitioner, GP , "Medical worker", Nurse	
		Caregiver, "Care giver"	
		Family, Families, Relative	
Concerns	Mandatory	Acceptance, Acceptability	Privacy
		Adoption	Reliability, Safety, Security
		Accessibility, Accessible	Trust, Trustworthy, Trustworthiness
		Availability, Available	Usability, Usable, Ergonomics, Ergonomic, "Ease of use", "Easy to use"

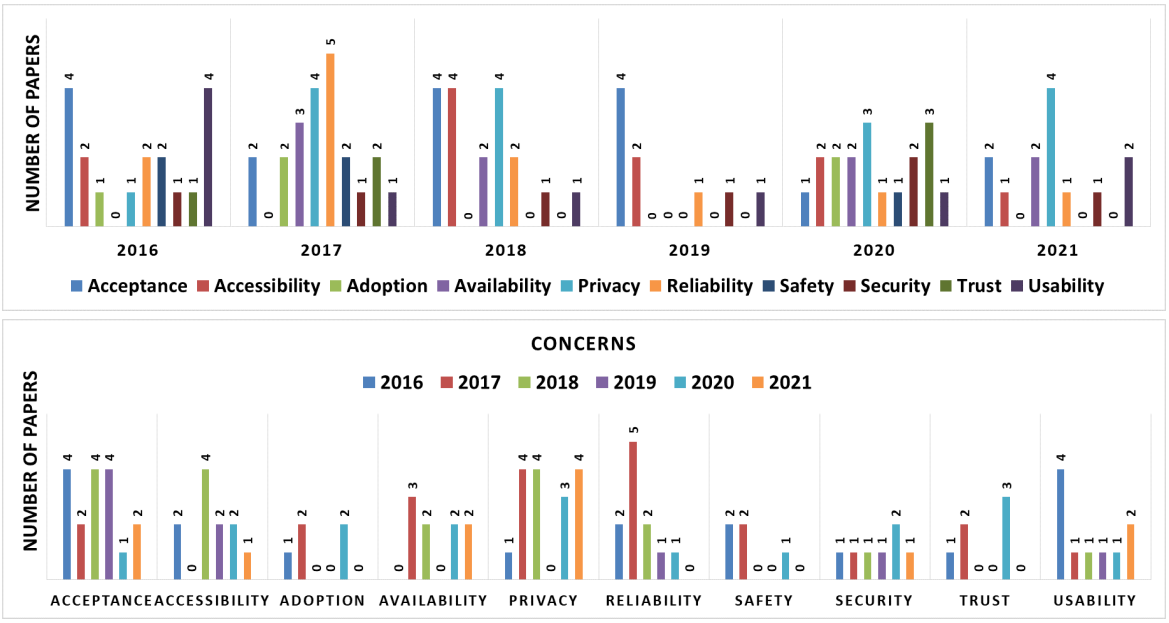

Figure 2: Top: the number and annual distribution of the papers concerning beneficiaries' concerns plotted per each year and per each concern from January 2016 to December 2021. Bottom: the number of papers plotted per each concern distributed per year

3.2 Concerns in AAL applications

The distribution of papers taking into account the possible beneficiaries' concerns is shown in Figure 2 per year and per concern. Each concern exhibits an irregular appearance throughout the considered period. The total number of papers published has a slight fluctuation, but it may be considered almost steady, with a peak in 2018, as shown in Figure 3 (a).

Acceptance is the top considered users' concern (i.e., 17 papers) [6, 8, 14, 18-31], with ***Privacy*** following very close (i.e., 16 papers) [6, 13, 22, 26, 30-41]. ***Reliability*** [24, 32, 33, 41-49], ***Accessibility*** [39, 50-59] and ***Usability*** [18, 20, 21, 23, 25, 28, 51, 60-62] are considered in 10 or more papers each (Figure 3 (b)). ***Availability*** [52, 61, 63 - 69] and ***Security*** [19, 39, 40, 46, 70 - 72] are slightly under 10; while the others, ***Adoption*** [12, 13, 58, 65, 73], ***Safety*** [18, 23, 65, 72, 74] and ***Trust*** [12, 13, 39, 46, 49, 75], appear in around five papers in the considered period. Overall, *Acceptance*, *Reliability* and *Usability* appear each year, whilst the appearance of the others is more jeopardized. Though the number of papers and the time frame is limited, it is worth noting that the papers considering

Usability has experiences a drop in the latest years, while those considering *Trust* appear to have a positive trend (Figure 2bottom).

Acceptance emerged as the most considered users' concern by the papers retrieved, thus evidencing the increased awareness of the research community that, only by putting enough attention on the acceptability of the delivered AAL solutions, developers can expect their uptake and long-term use [14]. *Acceptance* was often considered with respect to the use of assistive robots [18, 19, 24, 25], to the different types of interaction modalities [23] and the notifications provided by the AAL solution [29]. *Acceptance* was most commonly addressed with other concerns, namely *Usability* [20, 21, 23, 25, 28] and *Privacy* [6, 22, 26, 30, 31], thus evidencing the importance of these other concerns with respect to technology acceptability. Notably, *Privacy* also received a considerable attention in the selected period, which is likely due to the entering into force of the European General Data Protection Regulation (GDPR) in this period. GDPR mandates to meet data protection principles by design and by default, thus requiring that AAL solutions adopt appropriate methodologies for protecting beneficiaries' data and identity during collection, analysis and use [13]. Privacy protection was considered not only with respect to data transmission and exchange [39], but also with respect to the identification of the assisted and care individuals in the sensory data [6], especially in the visual ones. In this respect, privacy-preserving sensors, such as real time direction-sensitive accelerometers [33], radar-based sensors [22], state-change sensors [34] or depth cameras [32, 36, 38, 41], were adopted by some of the papers. Other approaches tried to retain all the informative richness of visual data acquired with RGB cameras, by working on visual data anonymization methods after acquisition [6, 30, 31]. One of the works addressed the privacy issue by adopting an edge computing approach [40]. In this case, security is another important question to be considered, as it was actually done by the authors. Overall, the security of the AAL applications and their data was less considered in the retrieved papers. Approaches based on user authentication and data encryption and isolation were the most common ones adopted [40, 46, 70, 71]. *Security* was sometime misinterpreted with *Safety*, as done in [19, 72]. *Safety* is actually defined and usually considered as the mandate to prevent any harm to the users from using the AAL system [18]. This concern was particularly considered with respect to human-robot interaction [19, 72] and to specific assisted beneficiaries, such as older and frail subjects [19, 23, 65]. An interesting solution to ensure safety made use of a simulator for testing the delivered AAL application [73]. *Reliability* was considered in several papers and usually targeted with respect to the accuracy and robustness of the AAL application delivered, especially when based on AI models [42 - 45, 47, 48]. The attention, in this case, was more on the technical capabilities of the applications as an indirect mean to ensure the acceptability by the end users and the beneficiaries, as evidenced by the fact that it is often considered along with acceptance, privacy and trust [32, 33, 41, 46, 49]. *Accessibility* corresponds to the convenience of reaching an AAL application. It was considered with respect to socio-demographic factors [59], based on race [50], economic aspects [54] or type of impairment [53, 58]. It was considered also coupled to *Usability* [51], which is another of the most addressed concerns. *Usability* is meant as the ease of use of an AAL application or system and is one of the necessary requirements of any computerized or electronic application. *Usability* was tackled in validation studies of the considered AAL application [18, 28, 61], especially with respect to cumbersome systems such as exoskeletons [62] or to the communication interfaces [23], as well as for presenting novel dedicated methods and scales for measuring it [21]. *Availability* was considered mainly in relation to a particular technology, as the possibility to use off-the-shelf technologies, such as mobile devices, in terms of services offered and cost [64, 65, 67, 69], or to have a continuously available service [63]. *Adoption* was considered as a more sustained and stable use and integration of the introduced technology into the beneficiaries' routine. Adoption was mainly addressed in surveys [12, 13] or technology-comparison studies [58, 73], as it is the final expected outcome of AAL solutions addressing the other beneficiaries concerns. Similar to *Adoption*, *Trust* is a complex construct and an emerging ethical concern that is receiving increasing interest in the AAL literature. The most recent European debate on the need to steer a beneficial development of AI solutions based on trustworthiness [76] has raised such an awareness also within the AAL community. Among the retrieved works, *Trust* was considered in policy-related papers [12, 13, 39] and pursued with respect to human-robot interaction [75] and home-care facilities, mainly in terms of reliability of the data processing methods [46] or the infrastructure [49].

3.3 Beneficiaries and scopes of the retrieved AAL applications

Older adults represent the largest beneficiary group of the retrieved AAL papers (39 papers) and they appear coupled to all the considered concerns. The target activities that the technology supports include activity recognition, mobility support and vital sign monitoring. For example, the research in [38] uses a set of RGB-D sensors to recognize at-home activities of daily living such as standing, sitting and walking. The study described in 24 employed a companion robot to help navigate older people at their homes, whereas work from [70] described devices for collecting and analyzing users' speech patterns to detect early stages of Alzheimer's disease. Frail persons (17) commonly referred to older adults at a higher risk of fall, or with a natural decline in functioning. The major role of AAL technologies was a support in various activities. The examples include a voice assistant to control home appliances for users with motor and cognitive impairments [58], or the Kinect device for pose recognition to early discover critical/emergent situations of people in need [37]. All concerns are considered also for frail end users. Patients (13) experiencing health decline were considered in different AAL-supported medical therapy, regardless of their age, for instance, for the actuation system of the T-FLEX ankle exoskeleton to support mobility of stroke patients [62], or augmented reality system that assists Alzheimer's patients in a tea-making task [28]. All concerns but *Adoption* and *Safety* were considered for patient end users.

Caregivers (12), healthcare staff (7) and family (3) were mentioned as supportive actors assisting in technology deployment. This way, they were mainly facilitators of target users' technology use. Accordingly, a mobile app was used to support informal caregivers for people with dementia [60] coupled with *Usability*, a

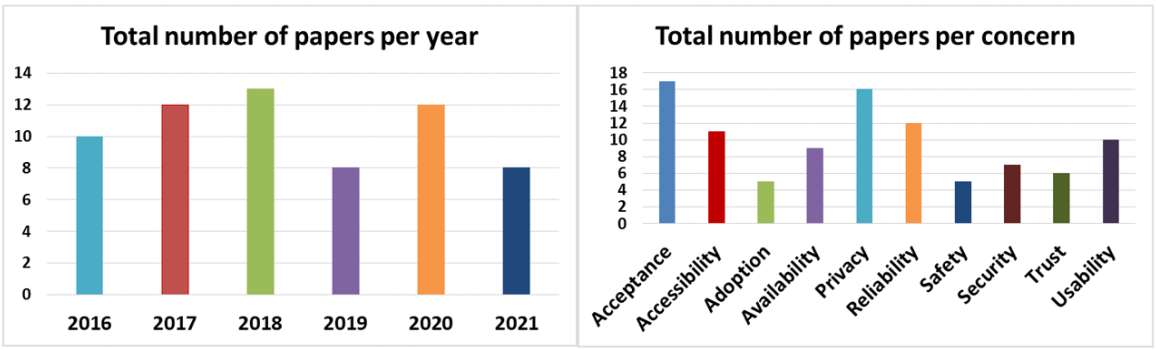

Figure 3: (Left) The numbers of total papers per year that consider at least a concern; (right) the total number of papers per concern

multi-agent system that recommends user actions outdoors based on obstacles observed in real time [53] coupled with *Accessibility*, and a feature-engineering tool for estimating physical activity levels and critical changes in users' medical conditions [46], coupled with *Reliability*, *Security* and *Trust*.

4 DISCUSSION AND CONCLUSIONS

For fully implementing the AAL potential, the underlying acceptance, adoption and ethical concerns should be addressed along with all the legal issues. The survey presented in this paper shows that the first solutions in this direction are starting to appear in the literature. Several papers are indeed considering not only technology-related issues, such as usability, reliability and security, but also other socio-ethical demands such as accessibility, privacy and trust and overall acceptance.

It should be acknowledged that the survey presented has some limitations, as, due to the digital libraries considered, for instance, some venues related to social and legal sciences may have been missed in the results, or some categories may have been enlarged with more synonyms. Nonetheless, the goal of the paper was to understand whether and how technological measures are being taken to address the AAL beneficiaries concerns. A more extensive analysis of the retrieved articles will be subject of future work. The results hereby presented are encouraging and suggest that a new generation of ethical- and social-aware AAL has started, although each of the work analyzed focus mainly on one or few of the beneficiaries' concerns. A comprehensive and throughout perspective is still missing, though it will be the only key towards the effective adoption and sustained usage of AAL technologies.

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REFERENCES

[1] Ger var den Broek, Filippo Cavallo, and Christian Wehrmann. 2010. AALIANCE Ambient Assisted Living Roadmap, IOS Press
[2] Joel J.P.C. Rodrigues, Dante Borges de Rezende Segundo, Heres Arantes Junqueira, Murilo Henrique Sabino, Rafael Maciel Prince, Jalal Al-Muhtadi, and Victor Hugo C. De Albuquerque. 2018. Enabling Technologies for the Internet of Health Things. IEEE Access, 6, 13129-13141
[3] Caroline A. Byrne, Rem Collier, and Gregory M.P. O'Hare. 2018. A Review and Classification of Assisted Living Systems. MDPI Information, 9, 182
[4] Stephanie Blackman, Claudine Matlo, Charisse Bobrovitskiy, Ashley Waldoch, Mei Lan Fang, Piper Jackson, Alex Mihailidis, Louise Nygård, Arlene Astell and Andrew Sixsmith. 2016. Ambient Assisted Living Technologies for Aging Well: A Scoping Review J. Int. Syst.,25,1, 55-69
[5] Andrea Carboni, Dario Russo, Davide Moroni, Paolo Barsocchi. 2021. Success and Hindrance Factors of AHA-Oriented Open Service Platforms. In Proceedings of the International Conference on Computational Collective Intelligence, Spinger, Cham, Rhodes, Sept 2021, 656-668
[6] Francisco Florez-Revuelta, Alex Mihailidis, Martina Ziefle, Liane Colonna and Susanna Spinsante. 2018. Privacy-Aware and Acceptable Lifelogging services for older and frail people: the PAAL project", 2018 IEEE 8th International Conference on Consumer Electronics - Berlin (ICCE-Berlin), 1-4
[7] Pireh Pirzada, Adriana Wilde, Gayle Helane Doherty and David Harris-Birtill. 2022. Ethics and acceptance of smart homes for older adults, Informatics for Health and Social Care, 47:1, 10-37, DOI: 10.1080/17538157.2021.1923500
[8] Ine D'Haeseleer, Kathrin Gerling, Dominique Schreurs, Bart Vanrumste, and Vero Vanden Abeele. 2019. Ageing is Not a Disease: Pitfalls for the Acceptance of Self-Management Health Systems Supporting Healthy Ageing. In Proc 21st Int ACM SIGACCESS. ACM, New York, NY, USA, 286–298. DOI:https://10.1145/3308561.3353794
[9] Martina Ziefle and Wiktoria Wilkowska. 2014. Why traditional usability criteria fall short in ambient assisted living environments. In Proceedings of the 8th PervasiveHealth '14. ICST Brussels, BEL, 218–222.
[10] AAL Guidelines for Ethics, Data Privacy and Security. AAL Program, 2020 http://www.aal-europe.eu/wp-content/uploads/2020/08/AAL-guidelines-for-ethics-final-V2.pdf (last accessed: 18/03/2022)
[11] Andraž Petrovčič Peek Sebastiaan, and Dolničar Vesna. 2019. Predictors of Seniors' Interest in Assistive Applications on Smartphones: Evidence from a Population-Based Survey in Slovenia" Int J of Environmental Research and Public Health 16, 9, 1623, MDPI https://doi.org/10.3390/ijerph16091623
[12] Josephine McMurray, Gillian Strudwick, Cheryl Forchuk. 2017 The Importance of Trust in the Adoption and Use of Intelligent Assistive Technology by Older Adults to Support Aging in Place: Scoping Review Protocol. JMIR Res Protoc, 6, 11:e218 DOI: 10.2196/resprot.8772
[13] Salifu Yusif, Jeffrey Soar, and Abdul Hafeez-Baig. 2016. Older people, assistive technologies, and the barriers to adoption: A systematic review. International Journal of Medical Informatics, 94, 112-116, Elsevier, https://doi.org/10.1016/j.ijmedinf.2016.07.004
[14] Björg Thordardottir, Agneta Malmgren Fänge, Connie Lethin, *et al.* 2019. Acceptance and Use of Innovative Assistive Technologies among People with Cognitive Impairment and Their Caregivers: A Systematic Review. BioMed Research Int, Hindawi, https://doi.org/10.1155/2019/9196729.
[15] Frederick Steinke, Tobias Fritsch, Daniel Brem, and Svenja Simonsen. 2012. Requirement of AAL systems: older persons' trust in sensors and characteristics of AAL technologies. In Proc of the 5th PETRA '12. ACM, New York, NY, USA, Article 15, 1–6. DOI:https://10.1145/2413097.2413116
[16] Eftim Zdravevski, Petre Lameski, Vladimir Trajkovik, *et al.* 2019. Automation in systematic, scoping and rapid reviews by an NLP toolkit: a case study in enhanced living environments. In: Ganchev I, *et al.* eds. Enhanced Living Environments: Springer, Cham; 1-18. ISBN: 978-3-030-10751-2
[17] David Moher, Alessandro Liberati, Jennifer Tetzlaff, Douglas G. Altman for the Prisma Group. 2009. Preferred reporting items for systematic reviews

and meta-analyses: the PRISMA statement. PLoS medicine, 6, 7:e1000097. doi: 10.1136/bmj.b2535

[18] Sebastian Glende, Isabel Conrad, Livia Krezdorn, Susann Klemcke and Carola Krätzel. 2016. Increasing the Acceptance of Assistive Robots for Older People Through Marketing Strategies Based on Stakeholder Needs. Int J of Soc Robotics 8, 355–369 (2016). https://doi.org/10.1007/s12369-015-0328-5

[19] Peter Mayer, and Paul Panek. 2016 [Should assistive robots have a "personality"?: Potential of simplified robot personalities]. Z Gerontol Geriatr. Jun;49, 4:298-302. German. doi: 10.1007/s00391-016-1068-3

[20] Stephen Czarnuch, Rose Ricciardelli, and Alex Mihailidis. 2016. Predicting the role of assistive technologies in the lives of people with dementia using objective care recipient factors. BMC Geriatr. 2016 Jul 20;16:143. doi: 10.1186/s12877-016-0314-2

[21] Ana Isabel Martins; Anabela G. Silva; Alexandra Queirós, and Nelson Pacheco Rocha. 2016. Validation of a usability evaluation scale for ambient assisted living products or services according to the evaluator's perspective. In Proc. 11th CISTI, 2016, pp. 1-6, doi: 10.1109/CISTI.2016.7521444

[22] Giovanni Diraco, Alessandro Leone, and Pietro Siciliano. 2017. A Radar-Based Smart Sensor for Unobtrusive Elderly Monitoring in Ambient Assisted Living Applications Biosensors 7, 4: 55. https://doi.org/10.3390/bios7040055

[23] Imad Alex Awada, Irina Mocanu, Adina Magda Florea, and Bogdan Cramariuc. 2017. Multimodal Interface for Elderly People," 2017 21st International Conference on Control Systems and Computer Science (CSCS), 2017, pp. 536-541, doi: 10.1109/CSCS.2017.82.

[24] Katalin Zsiga, András Tóth, Tamás Pilissy, Orsolya Péter, Zoltán Dénes, and Gábor Fazekas. 2018. Evaluation of a companion robot based on field tests with single older adults in their homes. Assist Technol. 30,5:259-266. doi:10.1080/10400435.2017.1322158

[25] Christiana Tsiourti, *et al.* 2018. A Virtual Assistive Companion for Older Adults: Design Implications for a Real-World Application. In: Bi, Y., Kapoor, S., Bhatia, R. (eds) Proceedings of SAI Intelligent Systems Conference (IntelliSys) IntelliSys 2016. Lect N inNetworks and Systems, vol 15. Springer

[26] Nancy E. ElHady and Julien Provost. 2018. Towards Sensor Failure Detection in Ambient Assisted Living: Sensors Correlations. IEEE 14th International Conference on Automation Science and Engineering (CASE), 2018, pp. 378-383, doi: 10.1109/COASE.2018.8560367

[27] Andraž Petrovčič, Peek Sebastiaan, and Dolničar Vesna. 2019. Predictors of Seniors' Interest in Assistive Applications on Smartphones: Evidence from a Population-Based Survey in Slovenia" Int J of Environmental Research and Public Health 16, 9, 1623, MDPI https://doi.org/10.3390/ijerph16091623

[28] Nina Rohrbach, Philipp Gulde, Alan Robert Armstrong, *et al.* 2019 An augmented reality approach for ADL support in Alzheimer's disease: a crossover trial. J Neuroeng Rehabil. 16,1:66. Published 2019 Jun 3. doi:10.1186/s12984-019-0530-z

[29] Loïc Caroux, Charles Consel, Margaux Merciol, and Hélène Sauzéon. 2020. Acceptability of notifications delivered to older adults by technology-based assisted living services. Univers. Access Inf. Soc. 19, 3 (Aug 2020), 675–683. DOI:https://10.1007/s10209-019-00665-y

[30] Pau Climent-Pérez, and Francisco Florez-Revuelta. 2021 Protection of Visual Privacy in Videos Acquired with RGB Cameras for Active and Assisted Living Applications. Multimedia Tools and Applications, January 22, 2021. https://doi.org/10.1007/s11042-020-10249-1.

[31] Wiktoria Wilkowska, Julia Offermann-van Heek, Francisco Florez-Revuelta, and Martina Ziefle. 2021. Video Cameras for Lifelogging at Home: Preferred Visualization Modes, Acceptance, and Privacy Perceptions among German and Turkish Participants. Intl J of Hum–Comp Int, 37, 15

[32] Sowmya Kasturi, and Kang-Hyun Jo. 2017. Human fall classification system for ceiling-mounted kinect depth images. 17th International Conference on Control, Automation and Systems (ICCAS), IEEE 1346-1349, doi: 10.23919/ICCAS.2017.8204202.

[33] Shaikh Farhad Hossain, Zahurul Islam, and Liakot Ali. 2017. Real time direction-sensitive fall detection system using accelerometer and learning classifier, 4th International Conference on Advances in Electrical Engineering (ICAEE), 2017, 99-104, doi: 10.1109/ICAEE.2017.8255335.

[34] Aleksandra Zdravevska, Ace Dimitrievski, Petre Lameski, Eftim Zdravevski, and Vladimir Trajkovik. 2017. Cloud-based recognition of complex activities for ambient assisted living in smart homes with non-invasive sensors, IEEE EUROCON 2017, 769-774, doi: 10.1109/EUROCON.2017.8011214.

[35] Manola Ricciuti, Susanna Spinsante, and Ennio Gambi. 2018. Accurate Fall Detection in a Top View Privacy Preserving Configuration. Sensors (Basel). 18,6:1754. doi:10.3390/s18061754

[36] Hossein Malekmohamadi, Armaghan Moemeni, Ahmet Orun, and Jayendra Kumar Purohit. 2018. Low-Cost Automatic Ambient Assisted Living System," 2018 IEEE Int Conf on PerCom Workshops,693-697, doi: 10.1109/PERCOMW.2018.8480390.

[37] Bruna Maria Vittoria Guerra, Stefano Ramat, Giorgio Beltrami, and Micaela Schmid. 2020. Automatic Pose Recognition for Monitoring Dangerous Situations in Ambient-Assisted Living. Front Bioeng Biotechnol. 2020;8:415. Published 2020 May 14. doi:10.3389/fbioe.2020.00415

[38] Shahram Payandeh and Jim Park. 2020. Passive Observer of Activities for Aging in Place Using a Network of RGB-D Sensors. Int J Telemed Appl.2020:8867926. Published 2020 Oct 23. doi:10.1155/2020/8867926.

[39] Laura X. Fadrique, Dia Rahman, Helene Vaillancourt, *et al.* 2020. Overview of Policies, Guidelines, and Standards for Active Assisted Living Data Exchange: Thematic Analysis JMIR Mhealth Uhealth, 8, 6:e15923 doi: 10.2196/15923

[40] Abu Sufian, Changsheng You, and Mianxiong Dong. 2021. A Deep Transfer Learning-based Edge Computing Method for Home Health Monitoring. 55th Annual Conference on Information Sciences and Systems (CISS), 2021, 1-6, doi: 10.1109/CISS50987.2021.9400321.

[41] Jennifer Lumetzberger, Ali Raoofpour, and Martin Kampel. 2021. Privacy preserving getup detection. In The 14th PErvasive Technologies Related to Assistive Environments Conference (PETRA 2021). ACM, New York, NY, USA, 234–243. DOI:https://doi.org/10.1145/3453892.3453905

[42] Óscar Belmonte-Fernández, Adrian Puertas-Cabedo, Joaquín Torres-Sospedra, Raúl Montoliu-Colás, and Sergi Trilles-Oliver. 2017. An Indoor Positioning System Based on Wearables for Ambient-Assisted Living. Sensors 17, 1: 36. https://doi.org/10.3390/s17010036

[43] Kadian Davis, Evans Owusu, Vahid Bastani, Lucio Marcenaro, Jun Hu, Carlo Regazzoni, and Loe Feijs. 2016. Activity recognition based on inertial sensors for Ambient Assisted Living. In Proc. of the 19th International Conference on Information Fusion (FUSION), 371-378

[44] Julia Richter, Christian Wiede, Enes Dayangac, *et al.* 2016. Activity Recognition for Elderly Care by Evaluating Proximity to Objects and Human Skeleton Data. In: Pattern Recognition Applications and Methods. ICPRAM 2016. LNCS, l 10163. Springer,doi.org/10.1007/978-3-319-53375-9_8

[45] Alexandra Danial-Saad, and Lorenzo Chiari. 2017. Developing an Assessment (Tool) for Touch Screen Devices. Stud Health Techn Inf, 242:755-761

[46] Eftim Zdravevski *et al.* 2017. Improving Activity Recognition Accuracy in Ambient-Assisted Living Systems by Automated Feature Engineering, in IEEE Access, vol. 5, pp. 5262-5280, 2017, doi: 10.1109/ACCESS.2017.2684913

[47] Shengyun Liang, Tianyue Chu, Dan Lin, Yunkun Ning, Huiqi Li, and Guoru Zhao. 2018. Pre-impact Alarm System for Fall Detection Using MEMS Sensors and HMM-based SVM Classifier. 40th IEEE Eng in Med and Biol Soc (EMBC), 2018, 4401-4405, doi: 10.1109/EMBC.2018.8513119.

[48] S.R. Rashmi, Sameia Suha, R. Krishnan, and Ramesh Babu. 2019. Alzh-care: - Knowledge - driven intelligent system to assist Alzheimer Patients. In Proc. of the 1st Int Conf on Advanced Tech in Intelligent Control, Envir, Comp & Com Eng (ICATIECE), 114-120

[49] Carmelo Ardito, Tommaso di Noia, *et al.* 2020. Towards a Trustworthy Patient Home-Care Thanks to an Edge-Node Infrastructure. In: Bernhaupt, R., Ardito, C., Sauer, S. (eds) Human-Centered Sof Eng. HCSE 2020. LNCS 12481. Springer, https://doi.org/10.1007/978-3-030-64266-2_11

[50] Daudet Ilunga Tshiswaka, Shondra Loggins Clay, Chung-Yi Chiu, *et al.* 2016. Assistive technology use by disability type and race: exploration of a population-based health survey. Disabil Rehabil Assist Technol. 2016 Feb; 11,2, 124-132. doi: 10.3109/17483107.2015.1090487

[51] Ana Isabel Martins, Alexandra Queirós, Anabela G. Silva, and Nelson Pacheco Rocha. 2016. Usability evaluation of ambient assisted living systems using a multi-method approach. In Proc of the 7th Int Conf DSAI 2016. ACM, New York, NY, USA, 261–268. DOI:https://10.1145/3019943.3019981

[52] Rebecca Jamwal, Libby Callaway, Louise Farnworth, and Di Winkler. 2018. Electronic assistive technology use in Australian shared supported accommodation: rates and user characteristics. Disabil Rehabil Assist Technol., 13,7:634-640. doi:10.1080/17483107.2017.1360948

[53] Sameh Triki and Chihab Hanachi. 2018. A Self-adaptive System for Improving Autonomy and Public Spaces Accessibility for Elderly. In: Jezic, G., *et al.* (eds) KES-AMSTA 2017. Smart Inn, Syst and Techn, 74. Springer, Cham. https://doi.org/10.1007/978-3-319-59394-4_6

[54] Rebecca A Matter, and Arne H Eide. 2018. Access to assistive technology in two Southern African countries. BMC Health Serv Res. 18, 1:792. doi:10.1186/s12913-018-3605-9

[55] Ha-Duong Bui and Nak Young Chong. 2018. An Integrated Approach to Human-Robot-Smart Environment Interaction Interface for Ambient Assisted Living, IEEE Workshop on Advanced Robotics and its Social Impacts (ARSO), 2018, pp. 32-37, doi: 10.1109/ARSO.2018.8625821

[56] Robert Hughes, Fadi Muheidat, Mason Lee, and Lo'ai A. Tawalbeh. 2019. Floor Based Sensors Walk Identification System Using Dynamic Time Warping with Cloudlet Support. IEEE 13th ICSC, 2019, pp. 440-444, doi: 10.1109/ICOSC.2019.8665560

[57] Andrew McNeill, Miglena Campbell, and Lynne Coventry. 2019. The quantified older adult as design requirements for accessible wellbeing interventions. In Proceedings of the 12th ACM PETRA'19. ACM, New York, NY, USA, 59–68. DOI:https:///10.1145/3316782.3321533

[58] Fabio Masina, Valeria Orso, Patrik Pluchino *et al.* 2020. Investigating the Accessibility of Voice Assistants With Impaired Users: Mixed Methods Study. J Med Internet Res. 2020;22(9):e18431. doi:10.2196/18431

[59] Monica Jamali-Phiri, Ikenna D Ebuenyi, Emma M Smith, Juba Alyce Kafumba *et al.* 2021. Socio-Demographic Factors Influencing the Use of Assistive Technology

among Children with Disabilities in Malawi. Int J Environ Res Public Health. 18, 6:3062 doi:10.3390/ijerph18063062

[60] Lena Rettinger, Lucia Zeuner, Katharina Werner, *et al.* 2020. A mixed-methods evaluation of a supporting app for informal caregivers of people with dementia. In Proceedings of the 13th ACM PETRA'20. ACM, New York, NY, USA, Article 46, 1–8. DOI:https:// 10.1145/3389189.3397981

[61] Diogo Abrantes, Soraia Teles, Rita Tavares de Sousa, Alberto Freitas, Pedro Vieira-Marques, and Ana Ferreira. 2021. A Multipurpose Platform for Ambient Assisted Living (ActiveAdvice): Usability Study. JMIR Aging.;4, 1:e18164. doi:10.2196/18164

[62] Daniel Gomez-Vargas, Felipe Ballen-Moreno, Patricio Barria, *et al.* 2021. The Actuation System of the Ankle Exoskeleton T-FLEX: First Use Experimental Validation in People with Stroke. Brain Sci. 2021, 11, 412 https://doi.org/10.3390/brainsci1104041

[63] Jayneel Vora, Sudeep Tanwar, Sudhanshu Tyagi, Neeraj Kumar, and Joel J P C Rodrigues. 2017. FAAL: Fog computing-based patient monitoring system for ambient assisted living," 2017 IEEE 19th Healthcom, 2017,1-6, doi: 10.1109/HealthCom.2017.8210825.

[64] Hao Jiang, Thomas Gonnot, Won-Jae Yi, and Jafar Saniie. 2017 Computer vision and text recognition for assisting visually impaired people using Android smartphone," 2017 IEEE Int Conf on Electro Information Technology (EIT), 2017, pp. 350-353, doi: 10.1109/EIT.2017.8053384

[65] Henriëtte G Van der Roest, Jennifer Wenborn, Channah Pastink, Rose-Marie Dröes, and Martin Orrell. 2017 Assistive technology for memory support in dementia. Cochrane Database Syst Rev. 6(6):CD009627.

[66] Jonas Austerjost, Marc Porr, Noah Riedel *et al.* 2018. Introducing a Virtual Assistant to the Lab: A Voice User Interface for the Intuitive Control of Laboratory Instruments. SLAS Technol. 23,5:476-482. doi:10.1177/2472630318788040

[67] Stephanie Wäckerlin, Armin Gemperli, Diana Sigrist-Nix, and Ursina Arnet. 2020. Need and availability of assistive devices to compensate for impaired hand function of individuals with tetraplegia. J Spinal Cord Med. 43,1:77-87. doi:10.1080/10790268.2018.1479054

[68] Portia Y Cornell, Wenhan Zhang, Lindsey Smith, Shekinah Fashaw, and Kali S Thomas. 2020. Developments in the Market for Assisted Living: Residential Care Availability in 2017. J Am Med Dir Assoc., 21,11:1718-1723. doi:10.1016/j.jamda.2020.08.011

[69] Georgina R Chelberg, Maike Neuhaus, Adam Mothershaw, Ray Mahoney, and Liam J Caffery. 2021. Mobile apps for dementia awareness, support, and prevention - review and evaluation. Disabil Rehabil., 1-12. doi:10.1080/09638288.2021.1914755

[70] Erik M Fredericks, Kate M Bowers, Katey A Price, and Reihaneh H Hariri. 2018. CAL: A Smart Home Environment for Monitoring Cognitive Decline," 2018 IEEE 38th International Conference on Distributed Computing Systems (ICDCS), 1500-1506, doi: 10.1109/ICDCS.2018.00155.

[71] K. Sowjanya, and Mou Dasgupta. 2019. Secure Framework for Ambient Assisted Living System. In: Mandal, J., Mukhopadhyay, S., Dutta, P., Dasgupta, K. (eds) CICBA 2018. Comm in Comp and Inf Science, 1031. Springer, Singapore. https://doi.org/10.1007/978-981-13-8581-0_34

[72] Donghui Zhao, Junyou Yang, Dianchun Bai, Martin Onyeka Okoye, and Yokoi Hiroshi. 2020. Quantitative Estimation of Differentiated Mental Fatigue between Self-Rising Transfer and Multiple Welfare Robots-Assisted Rising Transfer. Electronics, 9,4:594. https://doi.org/10.3390/electronics9040594

[73] Anna Schlomann, Alexander Seifert, Susanne Zank, and Christian Rietz. 2020. Assis Technology and Mobile ICT Usage Among Oldest-Old Cohorts: Comparison of the Oldest-Old in Private Homes and in Long-Term Care Facilities. Res Aging. 42,5-6:163-173. doi:10.1177/0164027520911286

[74] Paolo Sernani, Davide Calvaresi, Paolo Calvaresi, Matteo Pierdicca, Enrico Morbidelli, and Aldo Franco Dragoni. 2016. Testing Intelligent Solutions for the Ambient Assisted Living in a Simulator. In Proc of the 9th ACM Int Conf on PETRA '16. ACM, New York, NY, USA, Article 71, 1–5

[75] Isabel Schwaninger. 2020. Robots in Older People's Living Spaces: Designing for Trust in Situated Human-Robot Interaction. In Companion of the 2020 ACM/IEEE HRI '20. ACM, New York, NY, USA, 600–602. DOI:https://10.1145/3371382.3377449

[76] HLEG on AI. 2019. Ethics Guidelines for Trustworthy AI - https://tinyurl.com/4tej3t38