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Challenges of ubiquitous and wearable solutions to address active ageing in the Andalusian community

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Abstract: Active ageing is a multidimensional process for achieving the potential quality of life and meaning in the life cycle. In the context of the Andalusian region in Spain, where the majority of the population is over 60 years old and lives in rural areas, it has become a key challenge. That is why the European projects within the Framework Programme for Research and Innovation, such as Pharaon - Pilots for Active and Healthy Ageing, promote technologies adapted by and for our elders. In the case of the Andalusian pilot, part of this project, we have selected a social network adapted to them, enabling them to communicate with the community at home and share their experiences. In addition, to improve their physical fitness, a device to count active minutes

and steps is included, which provides users and caregivers with a visible and objective metric of daily health status. The technology has been evaluated following a well-defined methodology, which is described in this work to promote the deployment of technology in large-scale pilots. A specific architecture (Information System for Active Ageing in Andalusia - ISA^3) and the components evaluated within a common ecosystem (Pharaon Project) are presented.

Keywords: Active ageing, Andalusia, ecosystem, wearable, ubiquitous computing
Categories: H.3.1, H.3.2, H.3.3, H.3.7, H.5.1
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1 Introduction

This paper addresses the impact of innovative services in the improvement of older well-being in terms of social interaction through the implementation of a strong methodological component of data analysis and service design including technology interoperability and validation.

Over the last decades, life expectancy at birth has increased by about 10 years in Europe [OECD, 2021]. The increase in life expectancy, combined with the decline in the birth rate in the previous century, has led to a reversal of the age pyramid in many European countries. The burden of disease and the reduction of well-being affect the elderly people, their families, and health, social and economic systems. Older people with health issues, disabilities or lack of autonomy need more health care and social support from their families, social economy institutions and health services to favour their social life and reduce loneliness cases [Choi, 2021].

As people approach the old age period, they may experience age-related problems and handicaps such as cognitive impairments and physical health, which lead to less productive roles and experience changes in social status, declines in interpersonal support and loss of health and loneliness [Adams, 2004]. It is well known that loneliness and quality of life (QoL) significantly affect psychological well-being [Yanguas, 2018]. Individual differences such as level of education, marital status, learned behaviours, social skills/hobbies and social support could affect loneliness. This situation has been worsened by the COVID-19 pandemic further hitting the socialisation capacity of older adults with dysfunction and fragility [Kasar, 2021].

As concerns the Andalucía region, a study [Jenkins, 2020], conducted by the Regional Ministry of Equality and including more than 2.000 people over the age of 55, suggests that people of all ages suffer from loneliness in all of the provinces of Andalucía, but that it worsens with age, especially for those who are 55+ years old. Its findings showed that loneliness strikes hardest people who are less educated and, more obviously, those who live alone. The findings also showed that eastern Andalucía, Malaga, Almeria, Granada and Jaen, have a higher percentage of loneliness than the western side.

In this regard, social isolation is increasingly recognised as an important public health issue. It is defined as "the relative absence of social relationships" [Smith, 2008]. Developing instruments to assess and address the levels of social isolation in a population is of paramount importance given that social engagement –i.e., the lack of social isolation– is a key pillar for good health, as recognized by the World Health Organization [WHO, 2021] (WHO). The Pharaon project (EU H2020 funded project),

and in particular the Andalusian Pilot is included in this context and it aims to be a fundamental brick within the local regional Active and Healthy Ageing policy-making to support and reduce older adults' social isolation pressure.

Pharaon (Pilots for Healthy and Active Ageing – available at https://cordis.europa.eu/project/id/857188) is an Innovation Action funded by the European Union's Horizon 2020 programme under the Grant Agreement n°857188 (www.pharaon.eu). This large-scale pilot project involves partners from 12 European countries and aims to achieve smart and active living for Europe's ageing population. Pharaon is creating a set of highly customizable interoperable open platforms to integrate advanced services, devices and tools including IoT, artificial intelligence, robotics, cloud computing, smart wearables, big data, and intelligent analytics. These solutions are going to be widely tested and validated, to respond to the needs of older adults and aim at enhancing the independence, safety, and capabilities of people as they age. The project is a collaboration of 41 organisations, led by the University of Florence (UNIFI), Italy, and will last 48 months (from December 2019 to November 2023). Pharaon adopts a user-centric approach and is going to test several digital solutions in 6 different pilots over 5 countries: Italy (Tuscany-Apulia), Spain (Murcia and Andalusia), the Netherlands (Twente), Slovenia (Isola) and Portugal (Coimbra-Amadora).

In this context, ubiquitous computing and Internet of Things (IoT) have emerged as a promising and disruptive technology to bring encouraging solutions which face challenges related to ageing populations [Bouchard, 2018] and eHealth applications [Bravo, 2018], improving the quality of care services and enabling people to remain independent in their homes for as long as possible [Rashidi, 2012]. The integration of technology into our daily lives in an immersive and transparent way was introduced by the term ubiquitous computing when technology takes a back seat [López-Medina, 2020]. From this visionary perspective in the early 1990s to our current concept of IoT, two key characteristics have been exploited in the last 30 years: low invasiveness of devices embedded in the environment and the use of connected smart devices that provide interpretable results by processing the collected data. The aim of this work presents ICT/IoT technologies to reduce older adults' social isolation and loneliness by enhancing autonomy and promoting social cohesion through connectivity and digital tools.

The platform here presented is called Information System for Active Ageing in Andalusia (ISA3), which includes a description of solutions based on: i) mobile devices, where a Social Network (Sentab) developed for elderly people is integrated, ii) wearable devices, which promotes the visibility of the activity health status using hip-worn devices (Miss Activity). The architecture enables the integration of solutions in a common ecosystem obtaining pseudonymized metrics of users for caregivers and Social Services. Additionally, methods and protocols for pre-evaluating the technology and analysing the current status of Andalusian elderly people are included.

The remainder of the paper is organised as follows: Section 2 describes the context and objectives of the Andalusian pilot. Section 3 presents the methodology carried out to evaluate the users and the technology and Section 4 presents the preliminary results of these evaluations. Finally, Section 5 presents future work and conclusions.

2 Description of Andalusian Pilot

In this section, a description of the social context of the Andalusian region and the technology integrated into the pilot is described. First, its socio-demographic environment, region and context are explained; and next, the Andalusian pilot proposed goals are presented. Second, the selected objectives and outcomes for Andalusian Pilot to face in the pilot deployment are described.

2.1 Presentation of population, region and context in Andalusia

Andalusia is the most populous autonomous community in Spain with almost 8,5 million inhabitants (8,472,407 in 2021; Instituto de Estadística y Cartografía de Andalucía). 62.2% of its area is classified as rural where mostly older people live. Specifically, the population over 65 is almost a million and a half (1,495,393 in 2021; Instituto Nacional de Estadística), putting it second among Spanish autonomous communities with the largest number of older adults. This segment has a high percentage of people in a situation of dependency, whose interventions are preferred to be developed at home [Pinzón-Pulido, 2016].

Due to its sociodemographic characteristics, it is estimated that 47% of older adults in Andalusia are lonely, and the percentage of people feeling alone in the vast rural areas may be even higher. Loneliness takes its toll on the physical and mental health of people that suffer from it. In fact, due to its significant impact, the Andalucia Council has created a Protocol for the Detection of Unwanted Loneliness of the Elderly in Andalusia [Igualdad, 2010]. In Andalusia, a significant part of the population over 65 years old (and especially over 80) are illiterate [Bolívar, 2010]. It is a sequel from:

- the 1936-1939 Civil War [Collelldemont,2015] [Núñez, 2003]
- the long years of Franco regime dictatorship, especially for women [Gil, 2009][García, 2014].
- the absence of a proper universal primary school system in Spain until 1970s (General Education Act of 1970) [Terrón,2017]
- the social and economic deficiencies that the Andalusian territory (and other areas of Spain) presented during much of the 20th century [Hoggart, 1997][Núñez, 2003]

Emerging from the conditions and characteristics of our territory, the Andalusian Pilot will directly face the Pharaon Challenges 4 (PCH4: Promote social cohesion) and 6 (PCH6: Reduce isolation and loneliness, enhancing autonomy through connectivity and digital tools), by the design and deployment of different use case scenarios which include the digital training to avoid digital exclusion in older adults, the reinforcement of the social links with community, peers, relatives and new friends, or the tools for share their long and valuable life-experience. Also, it can be understood that the scope of the Andalusian Pilot could cover indirectly the Pharaon Challenges 1 (PCH1: The behaviour and the approach of the elderly to friendly technological devices), through taking measures on techno-stress or user experience, and 2 (PCH2: Health status definition and its progress over time), through the planned scenario about active accompaniments and cognitive stimulation.

The approach of the Andalusian Pilot to achieve these goals is consistent with the scientific production around the relationships between the AHA experiences mediated by ICT solutions. Following the work of Barakovic et al. [Barakovic, 2020], the Pharaon project includes various digital devices, whose combination is intended to answer to the multiple dimensions of the QoL in older adults; specifically, the Andalusian Pilot will test services not oriented toward medical or pharmacological monitoring (complementing other approaches and Pharaon Pilot sites). Beyond other approaches based on a clinical perspective, which conceptualises health as a synonym of illness, the Andalusian Pilot tries to address the social and psychological dimensions of the health concept, through the increase of years lived in wellbeing and health, rather than only increasing life expectancy.

In the next Pharaon steps a validation of the deployed devices to end users will be carried out through the implementation of a broad and representative sampling (around 500 participants) and responding to most of the recommendations of the aforementioned article: investigate the relationship and balance between the different determinants of smart ageing, cover different QoL dimensions, promote the awareness of different stakeholders involved, and provide tools of independent living for older people, regardless of their habitat (the territorial scope of the Andalusian pilot is largely rural).

The planned measures about techno-stress, living alone at home as inclusion criteria, or the design of a use case to expand and strengthen the participant's community relationships is an operative way to investigate independent living, the personal thoughts and behaviours about technology using, and the influence of the older adults' social networks and surrounding organisations and institutions in their interaction with technological available devices [Peek, 2015]. The design of the research process and use cases also include the presence of ICT solutions in the day-to-day life of the older adults, an explicit scenario for the acquisition and improvement of digital skills, and the inclusion of supportive networks and services (volunteers, home care service, organisations and stakeholders which works on AHA), thus preventing the risk of inequities and the growth of the digital divide in the use of technology [Yang, 2019].

The aim to incorporate a cognitive stimulation scenario tries to fill in content and give practical and productive guidance to active accompaniment, including both in-home care services and community-based activities (associations, centres for senior citizens). Cognitive stimulation provides a valuable and pleasant entertainment time, promotes the improvement of psychological health, stimulates and maintains the cognitive skills of people who are disadvantaged due to their lack of literacy, and even prevents and predicts cognitive decline or several age-related impairments (supporting the professional decision making) or, at least, alert of its first symptoms. Synergies with home care service providers could support the innovative introduction of ICT solutions in the home and the daily life of the older adults, through the caregivers, people with whom there is a relationship based on trust and who can also benefit, through the recognition and revaluation of their professional and digital skills and avoiding [Gómez Bueno, 2020].

2.2 Objectives and outcomes of the Andalusian Pilot

The main objective of the Andalusian pilot is to reduce social isolation and loneliness by enhancing autonomy and physical activity promoting social cohesion through connectivity and digital tools. The Andalusian pilot is focused on 3 main scenarios with the aim of (1) palliating the digital divide in older adults by training technological skills, (2) stimulating social participation and avoiding isolation in the community through a virtual social network that in turn allows meetings between groups with common interests (Android device to create bonds of friendship), and (3) promote their physical well-being by monitoring their active minutes. The selected set of technologies will form an **Information System for Active Ageing in Andalusia (ISA^3)**, which covers the following scenarios:

- Improve digital skills: This scenario allows older adults to train their digital skills and promote the use of technology to facilitate digital inclusion and eradicate the digital divide in Andalusia and will allow Andalusian participants to have a fast and easy approach to technology and face up to the digital divide in some Andalusian rural areas. Technology covers this scenario by interacting with the device (using and handling the tablet), creating his/her user profile and contacting his/her caregiver through the device.

- Participate in the community: This scenario will allow older adults to connect and meet like-minded people with whom to share online and offline experiences, scheduling online activities that are organised in different circles and organisations so that they know the range of activities close to them in which they can register, collaborate and participate. Technology covers this scenario by accessing social networks, making video calls, using chat, managing activities, recording and sharing videos, watching videos, writing a comment or giving a like in a post, etc.

- Provide cognitive stimulation: This scenario allows older adults to train cognitive skills so that they provide active entertainment, promote psychological health and they predict cognitive decline or several age-related impairments. Likewise, the issue reports from the cognitive activity could provide support to professional decision-making and help to predict future cognitive decline or similar age-related impairments. Technology covers this scenario through the possibility of accessing various cognitive games and consulting their scores.

- Support Physical well-being**:** This scenario promotes their autonomy by monitoring their physical activity and daily mobility, receiving continuous feedback on their physical activity and being able to indicate their target number of steps and active minutes. The technology covers this scenario as MISS Activity has all the functionalities indicated.

3 Methods

In this section, we describe the methods of the pilot to deploy ISA^3 in the target population of Andalusia. First, the selection of elderly people based on suitable selection criteria is presented. Second, the description of technology involved, and metrics collected by the platform are described.

3.1 Presentation of population, region and context in Andalusia

The roles of users and inclusion and exclusion criteria to be considered for the Andalusian pilot for the scenarios are gathered in three main groups, which are shown in the following table and described in depth below:

	Inclusion Criteria	Exclusion Criteria
Older Adults	>65 years old People living alone; People who feel lonely; Basic digital skills (only for use cases "Participate in the community" and "Providing cognitive stimulation")	Presence of cognitive impairments (severe or moderate) Presence of severe sensorial issues.
Professionals	Digital Skills, proactive, motivation, experience with older adults	None

Table 1: Target users' profiles in the Andalusian Pilot

For the deployment of the pilot, the following have been recruited:

- **Older adults (n = 400):** People over 65 years old who live alone and/or feel alone, do not have cognitive impairment that prevents them from making decisions independently and who are either users of the services offered by the Regional Council of Jaén (home care service, workshops to promote social interaction, etc) or anyone from Andalusia who wishes to participate and meets the criteria of the study (they could be informal caregivers of other older adults).

- **Professionals (n = 25):** Professionals of reference in the care of older adults (psychologists, social workers, health workers...).

Type	Profile	Expected number of participants
Older adults	Older Adults living alone and/ or feeling loneliness	400

Professionals	Health professional and formal caregivers: social workers, occupational therapists, psychologists, auxiliaries….	25

Table 2: Expected number of participants in the Andalusian pilot

As for the location of the recruited users, the sample is distributed in the following Andalusian provinces, including small municipalities belonging to them: Jaén, Granada and Sevilla.

3.2 Description of technology involved and metrics

The Andalusian pilot, based on the objectives defined and outlined in section Objectives and outcomes of Andalusian Pilot 2.2, has mainly selected Sentab App (SENTAB), MISS Activity (Maastricht Instruments) and the middleware OneSait (INDRA) which collects data from heterogeneous platforms in a homogeneous data model to develop an architecture for ISA[3].

3.2.1 Sentab

The presentation of Sentab's functionalities is similar across the different platforms, although the user interface is optimised for each particular platform and user. First of all, SentabApp is a social network developed by and for seniors, fully adapted to their needs. It has a very intuitive interface for tablets with the main menu that encompasses access to all functionalities.

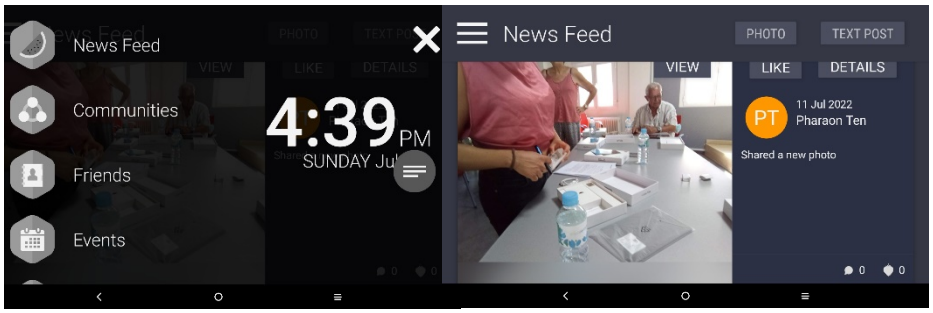

Figure 1: SentabApp for older adults interface

The platform stands out for its social discovery of other people, avoiding isolation and loneliness through video calls or chats, enabling different thematic "rooms" and group calls. It also has a news section, keeping seniors up to date with the latest developments and updates in their circle of friends and groups. Among its functionalities, we highlight:

- Ability to discover, link and connect with others through user search. This provides a connection between older people and their families and carers, as well as, a community collaboration led by the users themselves. In addition, anything they post appears in the news section and can be viewed by their contacts.

- Video and audio calls between contacts enable a straightforward interaction between elders without typing/writing requirements.

- Targeted communities, where users can sign up for different activities or organisations can disseminate local news to their community members.

- News section, where the user will get all the updates from their contacts. Supports text posts, events, polls and the ability to comment and specify "like" to contents.

- Periodic notifications where users are reminded to participate in cognitive games regularly to evaluate their cognitive performance or answer friend requests.

- Sentab Index consists of three indices: Physical Index, Social Index and Cognitive Index. Each of these can range from 1 to 10 and is communicated to users based on their progress. It is formed through a combination of cognitive games and answering pop-up questions after multimedia clips that test our users' short-term memory. This motivates users to strive for better results and can induce powerful patterns of behaviour change.

In the case of the application developed for caregivers, the interface is more complex and extends the functionality by adapting to the profile for which it is developed.

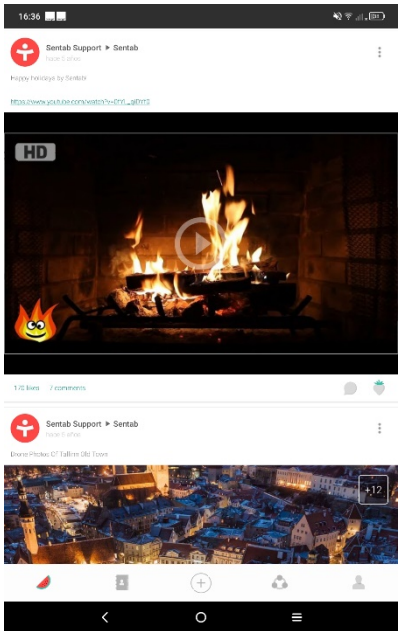

Figure 2: Example of posts in Sentab for caregivers interface

In terms of functionality, it includes all of the aforementioned except the sentab index. In addition, it adds the possibility of creating communities where users can join and be aware of all the activities, as well as creating events where they can add all the information so that interested older adults can sign up. As mentioned, Sentab covers the social and cognitive stimulation part.

3.2.2 MISS Activity

For physical stimulation, MISS Activity has been selected as a suitable and non-invasive solution for elderly people. It is an e-health tool motivating the elderly to be more active by enabling them to set goals and providing them insight into their activity that differs from conventional activity monitors/commercial wearables in that it is adapted to the target group.

- The device is very convenient, as it can be carried in a pocket and does not get in the way of everyday life.
- It validly and accurately measures only two variables: steps and active minutes.
- The algorithm is specially adapted to slow walking.
- The user interface of the app has been developed for older people and they are involved in the design.

- The data is displayed simply in the app. In the app, the user can see that day's data and the distribution of the number of steps and active minutes spread over the day. In the same app, the participant can indicate the personal step goal and the active minutes' goal.

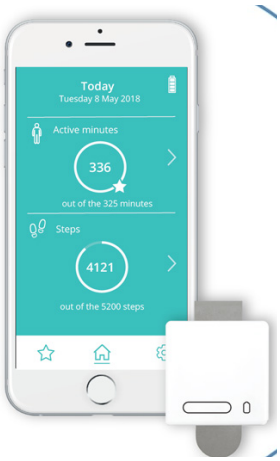

Figure 3: Miss Activity device and application

The data collected from Sentab and Miss Activity are uniquely visible for each user. In the global architecture of ISA^3, a process of Extracting, Transforming and Loading extracts pseudonymized data to be reported for caregivers and social services in a data mart. For that purpose, OneSait platform and relevant metrics have been defined to evaluate the performance and usage of the platform, which are described in the next Section.

3.2.3 OneSait Platform, developed by Minsait (Indra Activity)

In the upper layer, ISA^3 integrates as middleware the OneSait platform (mentioned above as the interoperable technology integration platform of the Andalusian pilot). Middleware is a layer of software above the operating system but below the application program that provides a common programming abstraction across a distributed system, it exists to help manage the complexity and heterogeneity inherent in distributed systems [Bakken, 2001].

Then, OneSait platform presents an integration layer of communication with data from heterogeneous services. It collects data from Sentab and MISS Activity backend, obtaining the metrics and KPIs to evaluate the impact of the technology. The backend of both platforms is in charge of centralising all requests and connections to the database, both from the application itself and from any external third-party platform that wants to interact with the data. In addition, both have OAuth2 security and authentication methods. In the case of Miss Activity, its backend system is very simple, as every time the user enters the application, a connection is made to the database that collects the current device information. No personal data such as name is available, only the device ID is collected. It has API-REST services through which the OneSait

platform makes requests to obtain the corresponding data. Only data per day is stored, as the value of the variables is replaced each time it is updated. The variables that are collected on Miss Activity are described below.

On the other hand, Sentab has a much more complex backend, as it has to manage requests related to a social network in real-time (video calls, friend requests, comments on posts, etc.) and therefore its database is also much more complex. Again, through API-REST services, the OneSait platform obtains the data necessary for the extraction of metrics. In this case, certain variables have been selected so that the data is completely anonymous, as Sentab does handle personal data. The email of each user is collected following the format ujapharaon1, ujapharaon2... so that the user maintains their privacy at all times, and each time a request is made, the information for that period is obtained in batches and stored in OneSait platform to extract the metrics. The variables that are collected on Sentab are described below.

The metrics from OneSait platform provide quantitative metrics on how the users (older adults, caregivers or informal caregivers) evolve in the use of technology in their daily life. This platform and its data will be used by data exploiters and researchers for research purposes only. In addition, Onesait Healthcare Data is certified in IHE ATNA (Audit Trail and Node Authentication) profile, which provides basic security aspects through access control, audit records and security in communications. In Figure 4, we describe the architecture of ISA^3.

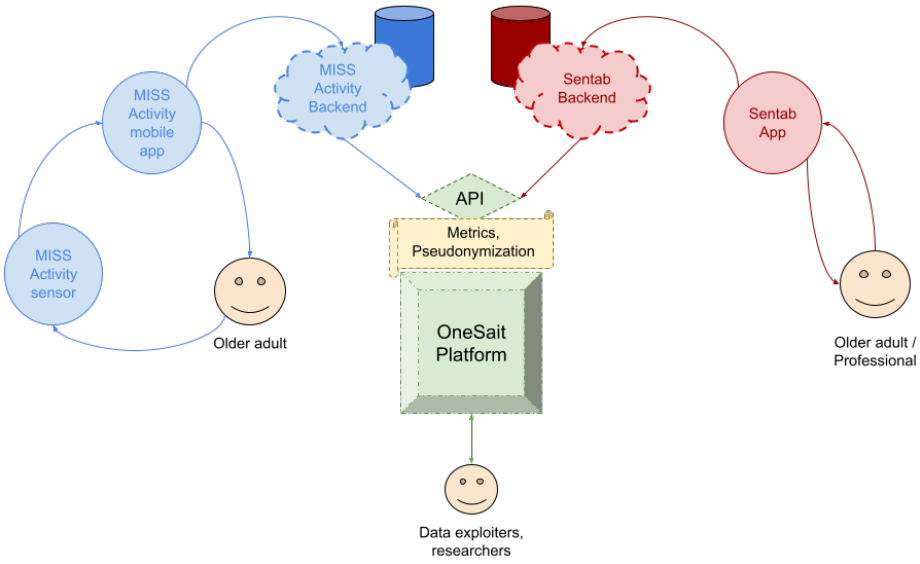

Figure 4: Architecture of ISA^3 system

Strict compliance with the GDPR, Organic Law 3/2018, of 5 December, on Personal Data Protection and Guarantee of Digital Rights, and other regulations, as well as the clear establishment of roles of Cybersecurity Officer and Data Controller, guarantee the security, traceability and confidentiality of the information associated

with users. The data collected falls under "non-sensitive data" according to the Spanish RGPD. In addition, we include the points of protection involving sensitive data to increase security under the principle of active responsibility. The principles of data protection by design and data protection by default apply, as well as minimisation of the processing of personal data, anonymisation/pseudonymisation of personal data and transparency regarding the functions and processing of personal data. Direct identifiers (i.e. names) are not included in the data matrix and are replaced by a code (anonymisation process). Indirect elements that could identify someone (i.e. age, living environment) will be aggregated during data analysis to avoid the possibility of indirectly identifying individual participants. The informed consent form will be the only document about the research process in which the identity of participants will be collected. These specific data will be stored separately, avoiding the identification of participants from the data hosted on the platform.

In ISA^3, as mentioned above, the architecture enables access to the technical data of third parties in an anonymised and aggregated form, which are uniquely collected in OneSait platform, so that the user's privacy and internal data or metadata are guaranteed at all times. Specifically, the data mart with pseudonymized data is stored as private data in an external module (persisted in a server which is located in Barcelona). It includes short general information on the profile, necessary only for the evaluation of KPIs in the pilot. An authorization module based on an authorization token will provide a token with credentials for a login session without personal information related to enabling access to non-personal data from other applications. The application layer integrated into apps of devices within the pilot will request data by API-based token access without personal data. Anonymized identifiers without personal information related will be handled in the background from application services. The access to the application data is checked by a cache of tokens and permissions generated and protected by the authorization module. In the exploitation of user data, data mining processes will generate metrics in data cubes which include aggregated information from a group of users, disabling the possibility of identifying a given person based on the data.

Data exploitation is possible due to OneSait's architecture. The exploitation of data and metrics is suitable for the dissemination of social and scientific research, as quantitative data on the use of technology in the Andalusian pilot are reported in real-time. The metrics include relevant KPIs:

- from Sentab time spent on the platform, number of video calls made, number of events attended, number of active minutes, number of friends, etc.
- from Miss Activity daily steps, daily active minutes, the intensity of the movement, and sedentary minutes.

In this way, we will directly obtain the impact of the technology on the users of the Andalusian pilot.

In addition, the ISA^3 platform presents an interactive dashboard with different graphs and visual representations of the data, giving the possibility to aggregate the data by different variables depending on what is needed. In figure 5, two metrics related to the Andalusian pilot technology are reflected in the interactive graphics. On Miss Activity, the total count of steps taken by the user is shown. On the left side, you can choose the user you want to consult and on the right side a graph with the total number

of steps per day. In the case of Sentab, it is interesting to know the number of times the user has switched from one screen to another (for example, from the news section to the communities section), which is reflected in the second graph in the image, being able to switch between users in the same way as with Miss Activity.

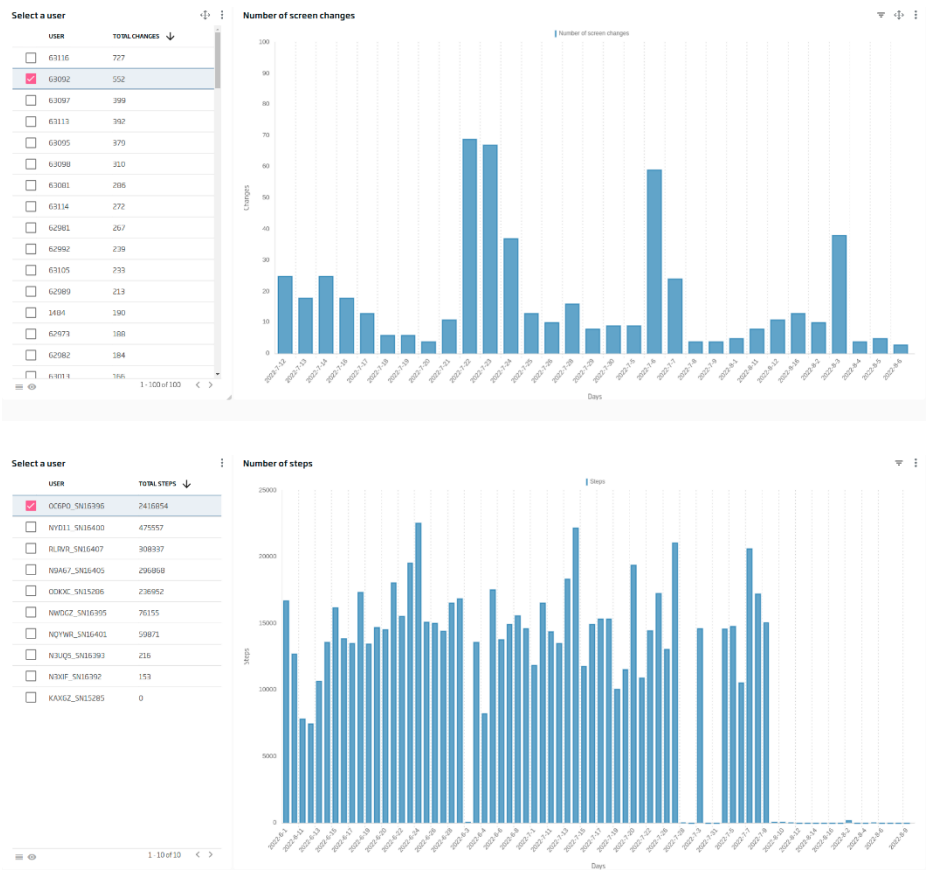

Figure 5: Screenshot from OneSait Platform

3.3 Description of methodology for evaluation

Andalusia's Pharaon Evaluation Framework aims at being the clear reference instrument to collect data and to support the impact assessment at Pilot Sites (PSs) level to generate an overall critical mass of evidence and quantified KPIs able to describe the generated impact. More in detail, the methodology aims to reach the following conceptual and procedural results:

1. To constitute a reference coherent evaluation framework to support impact assessment conducted at the Andalusia level through the inclusion of context-related KPIs and instruments for assessing pilot-specific impact,

2. To promote the reliability of data evidence thanks to the use of digital solutions,
3. To share a common glossary for service description and assessment outcomes representation,
4. To deliver guidelines and instruments supporting the scaling up and replication process of deployed AHA-IoT services.

To achieve such objectives, the evaluation process will be structured according to the following main 3 actions:

1. To evaluate the technology's impact to slow down the older adults' health decline or maintaining their health status for a longer period
2. To evaluate deployed services' users' acceptance
3. To evaluate deployed services' cost-effectiveness

The evaluation of the expected outcomes needs to take into proper account social and service determinants as independent variables that are, a priori, the main contributing factors of the changes on endpoints (dependent variables), according to the process described in Fig.8:

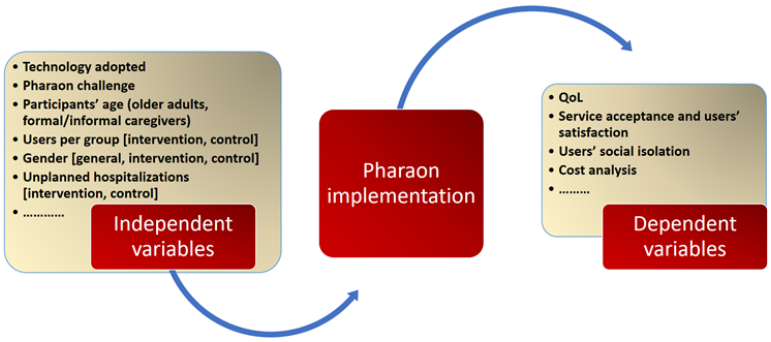

Figure 6: Pharaon's determinants.

Table 2 details independent variables, including Data Source and Data Collection timing.

Independent variable	**Data source**	**Data collection timing**
Age, Gender, Living and Working status, Tech. and Educ. Level, Pharaon challenge….	Socio-demographic Questionnaires	Baseline
Technology usage	Device/Server data logs	Average once every week
Pilot Site	Pilot site number	Once

Table 3: Independent variables, including Data Source and Data Collection timing

The Pharaon Evaluation methodology has been designed starting from a specific Study Hypothesis.

STUDY HYPOTHESIS

Digital technologies deployed in the PHARAON ecosystem are beneficial for elderly QoL management and deployed services are sustainable in the short-medium run from both elderly and public/private authorities' standpoints.

To address it, a strong co-design approach has been implemented and the Pharaon's Evaluation methodology has been based on the elements of a standard template for clinical studies. On top of this, the following Outcomes and Primary and Secondary end-points have been defined.

Primary Outcomes are that Pharaon deployed scenarios have a positive impact on the following end-points referring to the QoL category and cost-effectiveness. These outcomes are measured through the following secondary end-points: users' QoL (older adults-formal/informal caregivers), users' Social Isolation and cost-effectiveness.

Secondary Outcomes is that Pharaon deployed scenarios have a positive impact on the services Sustainability services: Sustainability (users' acceptance), Innovation & Growth (local services replication plans).

The table below reports the list of Global KPIs used to measure Pharaon's endpoints, their Data Sources and Data Collection Timing.

KPIs	Methods for data collection	Data collection timing
Sustainability category (Primary end-point)		
QoL	1) EQ-5D-3L (CarerQ-7D for formal/informal carers)	Baseline, intermediate and final analysis
Social Isolation	1) UCLA Loneliness scale version 3	Baseline, intermediate and final analysis
Cost Analysis	1) Cost-Utility Analysis (and ICER) 2) Willingness to Pay	Final analysis
QoL category (secondary end-point)		
Users' acceptance	2) SUS questionnaire ICT technologies usage	Miss Activity and Sentab: Baseline, intermediate and final analysis
Innovation and Growth category (secondary end-point)		
Local replication plans	No. of local replication plans for AHA-IoT services	Final analysis

Table 4: Global KPIs used to measure the Pharaon's endpoints, their Data Sources and Data Collection Timing

The methodology used in this project follows two complementary approaches. In the first place, the study contains numerous pre-validations that allow an iterative and incremental process that starts from a minimum viable product and improves until reaching the final product according to the decisions that will be made throughout the

project. This iterative process that contains 2 first pre-validations follows an agile methodology approach that allows, unlike waterfall development, to be tested by the stakeholders involved and to obtain feedback for its consecutive improvement in different phases. After the completion of the pre-validations, a pilot study will be carried out whose objective is the assessment of several Key Performance Indicators (related to sociodemographic, social and health variables, as well as usability, product value, etc.), which follows in a certain way some patterns of the MAFEIP methodology.

The MAFEIP methodology is an instrument that provides information in political decision-making after the assessment of this type of intervention (intervention evaluations with health technologies).

MAFEIP, unlike other methodologies, allows with a high degree of precision the value of the innovation carried out on the different interested parties and in this way systematizes the characteristics (scalability), the result and the impact of said intervention on health technologies on the different participants. In this sense, unlike other methodologies such as (quasi) experimental design of repeated measures where the impact of an intervention on several participants over time is evaluated, MAFEIP considers other parameters such as innovation, and the transfer of that knowledge to political decision-making and to the stakeholders involved. With this methodology, it is presented to evaluate the incremental profit with the objective of knowing the profitability and real applicability of the intervention that is proposed within that sociodemographic group and in this way help in the orientation of the decision-making of political groups or decision makers in different regions.

Focusing on real projects where methodologies can be compared, the ACTIVAGE [Wichert, 2021] project uses some of the questionnaires also used in Pharaon (Quality of Life Questionnaire for elderly (EQ-5D-3L), and local KPIs on the satisfaction changes over time) but the user participation is much more passive as it does not involve direct monitoring, only information is collected through the installed sensors. In the SMART BEAR project [Kouris, 2020], we observed major shortcomings in the description of questionnaires and surveys, being unable to replicate this in other large-scale pilots. This is common in the scientific literature on this topic, as it focuses more on the Information and Communication Technologies part than on the evaluation and monitoring of users and their integration. In works such as [Padyab, 2019], the importance of designing the methodology and technologies, and involving users as early as possible in the process so that it adapts to them is highlighted. However, most of them do not have experiences focused on older people. For these reasons, Pharaon is a key point in terms of the methodological process for large-scale pilots for older people.

4 Results

This section presents the results obtained in the Andalusian pilot. Firstly, the methodology followed to pre-validate the technology using quantitative and qualitative questionnaires on its usability and user feedback is presented in the first stage. Subsequently, the phases into which the pre-validation was divided are presented together with the results obtained. Secondly, the methodology was followed to evaluate our users before deploying the technology.

4.1 Prevalidation results

The prevalidation of the technology was divided into three phases so that two objectives were covered: to test the usage scenarios of the individual solutions, the national platforms (and the Pharaon ecosystem) to highlight possible technical problems (bugs) and improve the solutions/platforms before the deployment of the large-scale pilots (LSP), and to collect user feedback in terms of usability to check whether the defined user requirements are covered. To collect usability performance indicators related to assessing the difficulties and willingness to use and user satisfaction, two questionnaires were selected:

- **After Scenario Questionnaire (ASQ)**. The After Scenario Questionnaire or ASQ is a 3-question scale used to assess the difficulty with which a user perceives a task in a usability test. Developed by J.R. Lewis in 1995, this survey is popular for its simplicity. An average score of 5 or higher means that there is no difficulty with the scenario tested. The "Comment" section of the questionnaire will provide a qualitative part allowing the user to describe difficulties if any.

- **System Usability Scale (SUS)**. The SUS questionnaire is a well-known method developed by John Brooke in 1986, to get an overview of subjective usability evaluations. It is listed in ISO 9241 and consists of 10 items with a Likert scale. The result is a score between 0 and 100. An average score greater than or equal to 68 means acceptance of the solution by the users. If the score is lower than 68, technical suppliers will have to make some improvements.

As for the pre-validation phases, the first phase consisted of 2 months for the pre-validation of the chosen technologies in each pilot. This phase included technical testing (bug reporting) for all individual solutions, usability feedback and difficulties according to the ASQ and SUS questionnaire to have a usability benchmark for each solution. One session was organised for each user group where Sentab Vanilla App was tested by professionals and older adults. Pre-validation leaders together with pre-validation coordinators in Andalusia (University of Jaén), defined the items shown in Table 4, where the results are also shown:

Tested scenarios	***ASQ results from older adults***	***ASQ results from professionals***
Videocall	6,14	6,92
Modify profile	6,00	6,67
Chat	6,19	7,00
Access post	6,12	N/A
Access events	5,64	N/A

Delete information	6,21	N/A
Create post	N/A	6,08
Create event	N/A	6,75
Create community	N/A	6,42

	Older adults	***Professionals***
Average of SUS results	60,71	73,75

Table 5: Quantitative results of phase 1 for Sentab Vanilla App

According to the SUS results, this application was poorly adapted to older adults, who could not easily visualise the interface elements (X = 60.71). This can be explained by the fact that this technology was not developed for this type of user. However, caregivers/professionals appreciated this technology as acceptable (X = 73.75) and easily overcame the scenarios according to the KPI results.

The second phase consisted of 2 months for the pre-validation of each national platform. In the case of the Andalusian pilot, the national platform is Indra's OneSait, described in section 3.2.3. This phase focused on functional tests according to the defined scenarios that highlighted the technical failures of interoperability between the integrated solutions and with feedback on usability and difficulty according to ASQ and SUS, thus testing ISA3. As in the first phase, the second phase was also organised in 1 testing session with the pre-validation manager and team and the user group. In this phase, MISS Activity, SentabApp for tablets and Sentab Vanilla App were tested again.

In the case of MISS Activity a minimal integration of the platform via data files was performed, although it is now fully integrated via API. The tested scenarios are shown in the following table together with the results of the questionnaires:

Tested scenarios	***ASQ results from older adults***
Consult data from previous days	4,63
Consult actual goal	6,63
Fix new goal	6,27

Table 6: Quantitative results of phase 2 for MISS Activity integrated into OneSait platform

According to the results obtained in the ASQ, the only functionality that posed a difficulty was the consultation of previous days' data, as the rest obtained almost the maximum score. There were also no comments about difficulties in the visibility of the graphical interface. In the case of the second Sentab App (the application designed for older adults and transferred to tablets), the following scenarios were defined:

Tested scenarios	***ASQ results from older adults***
Join event	6,20
Like a picture	6,20
Change settings	4,80
Videocall	5,80
Play games	5,27
Cognitive index	5,47

Table 7: Quantitative results of phase 2 for Sentab App integrated into OneSait platform

Overall, according to the ASQ results, all functionalities were sufficiently accessible to older adults except for the application settings. The overall feedback on the technology was a marked improvement in the usability of the interface. Finally, the first Sentab App was only tested by its target group (professionals and caregivers) after its integration into the national platform. The scenarios defined for the ASQ are shown in Table 7 together with the results.

Tested scenarios	***ASQ results from older adults***
Interact with pictures	6,17
Leave a community	4,17

Table 8: Quantitative results of phase 2 for Sentab Vanilla App integrated into OneSait platform

According to the results, the option to leave a community was not yet available, so the score drops drastically. However, in the case of the professionals/caregivers, the qualitative comments were more relevant than the quantitative results, as they expressed which aspects of the application had improved compared to the previous phase.

4.2 Evaluation results of population

The preliminary results are made of 40 participants, 28 of whom are women, 10 are men, while the remaining two were not available. Our goal is to study the behaviour of those units in terms of quality of life related to their physical conditions and also from their psychological status point of view. Table 8 summarises the main statistics regarding the variables in our database. The number of men in the sample is almost a third of the number of women. Only two covariates showed missing entries regarding the unit Gender (2) and its Health status (17) at the time of the questionnaire filling.

Gender	Number of Men 10	Number of Women 28	Missing Values2 17
	Mean	Standard Deviation	
Health	54.22	19.86	
EQ.5D.3L	0.64	0.27	**ρ** - 0.568
UCLA V.3 Loneliness Scale	38.42	11.90	**p-value** < 0.001

Table 9: Descriptive Statistics

The correlation coefficient [Bravais, 1844] between the two continuous outcomes is −0.58 ($p = 0.001$), which would state a negative and quite strong correlation between physical and psychological well-being. To check the significance of that result, we first perform a Shapiro-Wilk test [Shapiro, 1965] to investigate those variables' normal distributions (p-value < 0.05); and consequently we run a non-parametric Spearman correlation test [Spearman, 1904] between the two continuous responses, which indeed rejects the null hypothesis regarding those variables independence. The following figures allow us to have a general overview of the conduct of the baseline scores of the units, by highlighting the main differences concerning the only one available demographic factor. Figure 7 represents a column chart for each outcome reminding the gender share on the total sample size and the average output for the two scores, divided by gender group. Those means are almost equivalent through the two groups from the physical well-being point of view, while by looking at Figure 8b, the UCLA loneliness score for the male group overcomes the female one by almost 10 points.

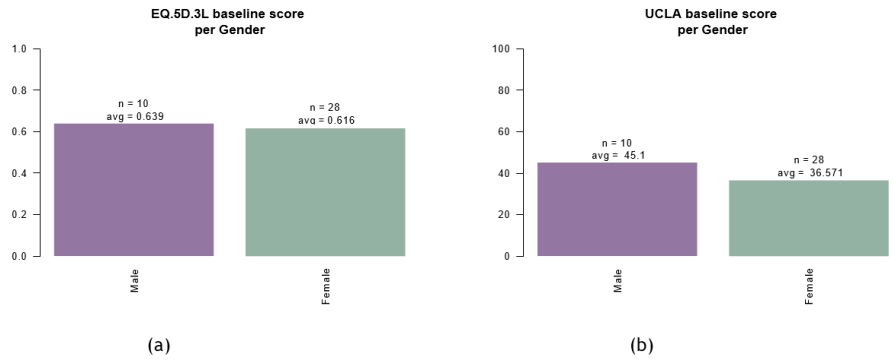

Figure 7: Barplots per Gender

While Figure 7 represents a point calculation of group sizes and means, Figures 8 and 9 help us to look into the respective unit's behaviour.

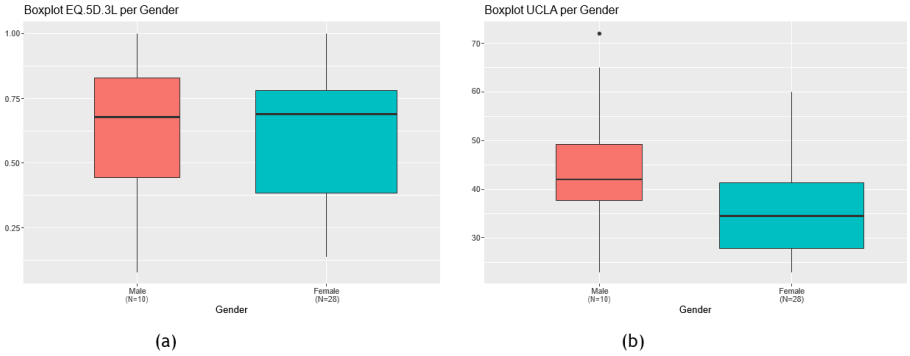

Figure 8: Boxplots per Gender

In particular, from Figure 8 we can investigate the attitude of all the units not only basing our knowledge on their score means but while in addition studying how they are distributed among the two groups. Indeed, looking at Figure 8a, even though the two group means are almost the same, we can now notice how the 50% quantile box [Shapiro, 1965] of females is considerably shifted down concerning the males. In addition, the EQ.5D.3L score means (black line) is much more centred in the red box, rather than in the blue box on the right hand of the figure. While Figure 8b confirms the first impression, we got from the column chart above: the two groups differ in both loneliness score mean and distribution.

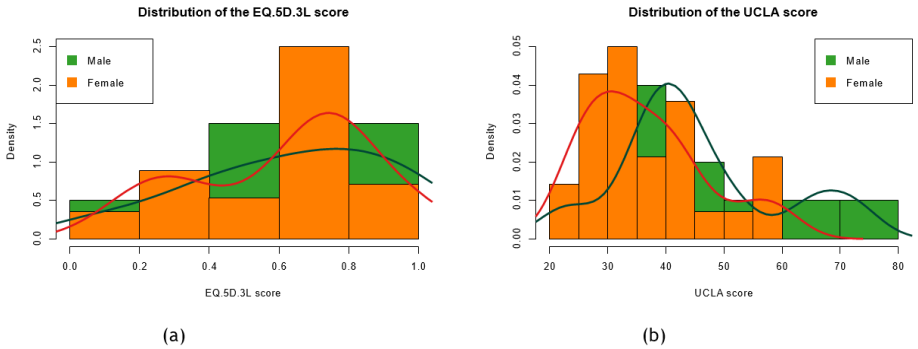

Figure 9: Boxplots per Gender

We describe the distribution of the scores between the two groups in Figure 9. The green bars and lines represent the males' scores, while the orange ones represent the females'. In Figure 9a, we get the idea that the green group of males is much more homogeneous than the orange one, which has another small peak at EQ.5D.3L equal to 0.3: this fact confirms the extended undersize of the blue box in Figure 9a. The two lines in Figure 9b are much more comparable in terms of their bell- shape, even though we notice a shift of the orange path to smaller UCLA score values, as expected from the previous analysis.

The above investigation gives a general framework of the baseline measurements from a descriptive perspective. From the correlation results between the two continuous outcomes (namely, EQ.5D.3L & UCLA scores), we have observed a negative output with respect to the interaction among those two variables. This might sound quite straightforward since we can naturally expect from a real-world scenario that a decrease in our physical well-being will very likely affect our humour and mental status, and vice-versa. Since this outcome from our analysis seems to be statistically robust, we may be able to think of extending those considerations around the topic to our general population. In addition, we got the idea of how the two main groups of data divided by gender status do appear relatively homogeneous with respect to their average values in both the physical well-being and loneliness scale, while they slightly differ regarding those responses' distribution among the two samples. However, we need to keep in mind the fact that the male group size is almost a third of the female one. Thus, those data behaviours not ought to be trusted as a significant representation of the underneath population they have been sampled from. Table 10 below summarizes the continuous measurements' correlation indexes. As already stated, we pointed out a negative trend of ρ between EQ.5D.3L and UCLA. The insertion of the other numeric factor which ranks the Health status seems to highlight a positive correlation with the physical component, and meanwhile a negative one, and almost identical with the first one mentioned in terms of strength, with respect to the other dependent variable measuring the psychological discomfort.

ρ	EQ.5D.3L	UCLA scale	Health
EQ.5D.3L	1.00	0.47	-0.59
UCLA scale	-0.59	1.00	-0.41
Health	0.47	-0.41	1.00

Table 10: Correlation Matrix between numerical responses

In order to check those correlation results' reliability, we performed a Least Squared linear regression model of the data-collected explicative covariates on each of the two outcomes of interest, taken one by one. The model results are reported in Table 11.

	EQ.5D.3L					UCLA			
Coefficients:	Estimate	Std. Error	p-value			Estimate	Std. Error	p-value	
(Intercept)	1.212	0.336	< 0.01	(***)	(Intercept)	62.437	5.609	< 0.001	(***)
Gender	-0.183	0.106	< 0.1	(*)	Gender	-9.116	3.420	< 0.05	(**)
Health	0.003	0.003	> 0.1		Health	-0.087	0.091	> 0.1	
UCLA	-0.017	0.005	< 0.01	(***)	EQ.5D.3L	-20.548	6.575	< 0.1	(*)

Table 11: OLS models on EQ.5D.3L and UCLA

The OLS regression model results tell us that there is not a significant effect of the variable Health status on either the physical well-being or the loneliness score (p-value > 0.1). This might be also due to a lack in the observation of the measure of interest, which presented a high proportion of missing entries with respect to the total sample size (17 over 40, 42.5 %). Then, we are not going to take that health component into account so far.

Something which is quite interesting is, in fact, the behaviour of the remaining two explicative covariates: as already stated several times, EQ.5D.3L and UCLA scores are in a statistically significant (***) negative association between each other. The estimated coefficients seem to underline a heavier effect of the first on the latter (-20.6 on UCLA scale - from 0 to 100), although with a slightly less significant test statistic (*), rather than the other way round (-0.02 on EQ.5D.3L scale - from 0.0 to 1.0). See the slight difference in slopes between lines in 4a and in 4b, for a visual representation.

Lastly, also the categorical factor related to the units' gender appears to be significant in computing both the outcomes of interest. Indeed, from the coefficient estimates derived from the Ordinary Least Squares regression model in Table 11, we can observe how a positive value of the variable Gender (i.e. being a Female) negatively affects the responses. This might tell us that a female subject has average lower EQ.5D.3L and UCLA scores than a male, by keeping constant all other characteristics.

A quite clear view of this phenomenon is shown in Figure 10. The drop-down trend of the OLS regression line between physical and psychological values is split into two leaves representing the behaviour of the two major sub-samples: the red lines, representing male records, are shifted towards higher physical well-being and loneliness values.

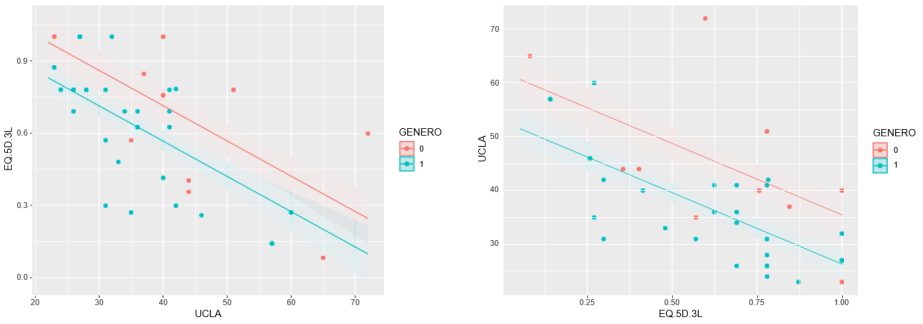

Figure 10: Ordinary Least Squares plots per Gender and Scores

5 Conclusions and ongoing works

In this study, we show the results of usability and acceptance of the technology from a pre-validation phase where it was found that even though the devices were not assessed with high difficulty by the participants (ASQ scores higher than 5 points), there was a low acceptance or some usability problems (SUS scores lower than 68) that should be improved in the technology.

In general, professionals compared to older people accepted and evaluated the tested technology with greater usability, this may be due to different key aspects related to the barriers that older people present in the use of technology (i.e. lack of digital skills, technology anxiety and confidence, previous experience, emotional aspects, etc., [Barnard, 2015] and in especially, a lack of adaptation of said technology to the characteristics of older participants.

In this sense, this pre-validation process has allowed us to locate the specific scenarios for the tested technology that we should focus on to improve the usability and acceptability of said technology. This project involves an iterative process that will allow us to improve the functionalities of the technology according to the scores obtained in the pre-validation results, bringing the technology closer to the profile of the user (Older people in the Andalusia region).

Likewise, as complementary results were found in the first phase of the pilot deployment, we find that the sample is mostly made up of women. These data are faithful to the distribution that is periodically thrown at the Institute for the Elderly and Social Services [IMSERSO, 2021] where approximately 70% of applicants for these benefits are women and the remaining 30% are men, as is the case in our sample.

This data is relevant since it allows us to know that the market niche where the developed services will potentially be used will be a potentially female niche and these characteristics must be taken into account, especially in the region for the tested technology. On the other hand, regarding the overall health status, older people have an average level of health. For its part, the level of loneliness was very high (since one of the inclusion criteria was "feeling or being alone"). For its part, it is found that self-

perceived health correlates negatively with self-perceived loneliness, this indicates that a person's better health is associated with a greater feeling of loneliness.

In the case of self-perceived health, no differences are found between men and women, however, in the loneliness scale, men have a higher mean score, since men, as described in the literature, are more prone to loneliness [Barreto, 2021].

Being able to describe the sociodemographic characteristics of our starting sample will allow us to increase the potential usability and acceptability of the technology that is being tested and developed in this project.

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