# Augmented Hearing Assistance for Elderly People
## *From Requirements to Implementation*

Pierre Barralon[1], Ivo Ramos Maia Martins[2], Nicole Merkle[3] and Stephanie Schwarz[4]
*[1]Heath Division, Tecnalia Research & Innovation, P. Mikeletegi, 20009, San Sebastian, Spain*
*[2] Research and Innovation, ATOS, Calle Viriato, 28040, Madrid, Spain*
*[3]Information Process Engineering, Forschungszentrum Informatik, Haid-und-Neu-Str., 76131, Karlsruhe, Germany*
*[4]Innovation Systems Department, Austrian Institute of Technology, Giefinggasse, 1210, Vienna, Austria*

Keywords: Remote Assistance, Health Management, Rules, Notifications, Medication Reminder, Voice User Interface, OpenAAL, Embedded Sensors.

Abstract: Remote assistance and health management are very important aspects in the EU funded AHEAD project. The AHEAD project aims on the combination and integration of innovative sensing devices already used by the elderly in their daily life (eyeglasses and hearing aid) with the Information and communications technology based modules in order to build a completely innovative remote monitoring product and services. This paper presents and discusses the data modelling, platform and services development, system integration and architecture out of technical perspectives.



## 1 INTRODUCTION

With the age increasing, hearing skills decay. With the use of assistive technology systems it is possible to preserve and improve the quality of life of elderly people with hearing losses. Currently few hearing aids have a wireless connectivity and for those which support it, it is done through a dedicated physical device which works as a gateway between the hearing aid and the smartphone (Starkey SurfLink Mobile 2 (Starkey, 2015), Phonak ComPilot (Phonak, 2015)). The low usability of such wireless solutions limits the services that can be delivered to the hearing impaired person. The project AHEAD (Augmented Hearing Experience and Assistance for Daily life) aims to make use of devices already accepted by elderly people in their daily life: eyeglasses and hearing aid. The combination and integration between advanced and innovative sensing with the ICT (Information and communications technology) based modules will result in a completely new and innovative product (and services). Both the eyeglasses and the typical hearing aid will embed a microphone. The hearing aid will not only be voice-controlled but will also become a communication device. As health management is important, the modified hearing aid will be able to measure vital signs such as heart rate, oxygen saturation and body temperature. These measurements can also be used for the user's emotional state detection and take action against symptoms of depression. Finally, a 3D inertial sensor records general activity and risky postural behaviours. Our assistant will be wirelessly connected to a smart phone and be a part of a smart living environment.

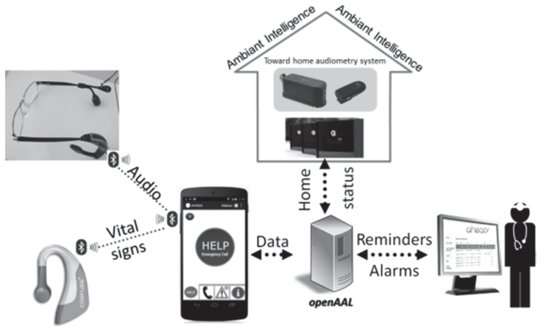


Figure 1: AHEAD first prototype.

This is used for compliance or for connecting the hearing aid to home automation systems and provide complementary services such as personal alarms (extension or replacement of the social alarm button), medication reminders, house warning, cooking and financial management assistance

Barralon P., Ramos Maia Martins I., Merkle N. and Schwarz S..
Augmented Hearing Assistance for Elderly People - From Requirements to Implementation.
DOI: 10.5220/0005445900590066
In *Proceedings of the 1st International Conference on Information and Communication Technologies for Ageing Well and e-Health* (ICT4AgeingWell-2015), pages 59-66
ISBN: 978-989-758-102-1

verbally conveyed into the wearer's ear.

In addition additional services currently developed in other Ambient Assisted Living (AAL) projects can be later added. For example, navigation support to hearing impaired people could be supported by the Assistant project (ASSISTANT 2012-2015). For users having eyesight decline HearMeFeelMe helps replacing visual and textual information with audio information (HearMeFeelMe 2012-2015).

# 2 USE CASES

To be able to work toward the project´s objectives, comprehensive use cases (Rashid, 2014) for emergency and phone calls, medication reminders, and audiometry self-verification testing respectively were defined in a first step, as described in detail in the following.

## 2.1 Emergency Call - Voice Command

An emergency call or alarm is triggered by a voice command generated by the user. This functionality is similar to current social alarm (push button) devices but triggered by voice instead:

a. The user pushes a button on the hearing device in order to engage a voice command, and is provided with a sound (message) letting him/her know that the system is waiting for a voice input.
b. The user says a specific "emergency" keyword. An audio message is streamed to the smartphone. Speech to text conversion is performed using Google API on the smartphone.
c. The message is sent to openAAL to be logged and to take decision if the command is an alert or not. In case of an alert openAAL returns to the smartphone a list of preferred phone numbers.
d. The AHEAD mobile app calls automatically the first number on the list (e.g. Emergency Call Center).

## 2.2 Emergency - Vital Signs

The user wears the AHEAD system equipped with the embedded physiological sensors which continuously monitor vital signs. Vital parameters (e.g. heart rate) of the assisted person are monitored and evaluated. Depending on the measured health state of the person, actions are triggered:

a. Vital values from the sensor are processed every second and sent to the openAAL platform. A dedicated software component analyses the evolution of the heart rate.
b. In case of values deviating from the desired values, an alert is triggered.
c. The openAAL platform sends to the mobile an action to perform: "make phone call". A list of phone numbers is provided.
d. The mobile phone automatically dials the first number in the list (e.g. Emergency Call Center).

## 2.3 Emergency Call - Push Button

An emergency call or alarm is triggered manually by the user interacting with the smartphone. This functionality is similar to current social alarm (push button) devices:

a. The user pushes a dedicated button on the screen.
b. A text message is sent to openAAL to be logged, and openAAL returns to the smartphone the preferred phone numbers.
c. AHEAD mobile app automatically calls the first number on the list.

## 2.4 Phone Call

A regular phone call is initiated by voice command like standard Bluetooth headsets:

a. The user pushes a button on the hearing device in order to engage a voice command and is provided with a sound (message) letting him/her know that the system is waiting for a voice input.
b. The user says a specific keyword and contact name (e.g. "call Peter").
c. The call is initiated.

## 2.5 Medication Reminder

The AHEAD system provides reminders to the user in taking his/her medicine in time:

a. Reminder information is introduced into the AHEAD system by the doctor.
b. Data (frequency, time, etc.) is transferred and stored into the openAAL platform.
c. If reminder conditions are met an event/message is sent to the smartphone indicating the message to transmit and the modality to be used (screen popup or synthetized voice).
d. The user receives the message and should acknowledge it.

## 2.6 Audiometry Verification Test

This test aims at establishing audiograms assessing a users' hearing capacity. The test stimulus is presented to the hearing-impaired user using inserts, headset or a free field speaker:

a. The user hears a voice repeating a stimulus word in different noisy environments (varying signal-noise ratio).
b. The user has to identify the stimulus word and tell his/her response to the audiologist
c. This sequence is repeated several times. Scores and graphics are later presented and discussed.

Based on these comprehensive use cases low-fi prototypes were developed and evaluated in a first iteration by elderly people within a lab user study.

## 2.7 Implications from User-centred Evaluation

The goal of the first user study was to gather usability and acceptance feedback of the first developed low-fi prototypes including the Emergency call via button press on the smartphone and via voice command using the hearing glasses, an early standalone prototype of the Audiometry verification test. Preferences for medication intake reminder sounds were collected. Fifteen elderly users aged between 60 and 79 years participated in this study. A mix approach of different quantitative and qualitative measurements was applied to gather first insights on usability and interactions aspects. A Nexus 5 cellphone and the hearing glasses prototype were used to evaluate the following services. The first user preferences regarding the type of initiation of an emergency call were explored. Users had to initiate an emergency call via speech-command (*active*), using specific key words such as "emergency", "call", "help". In the second task automatic emergency call according to severe vital-sign deviances was simulated (*passive*). The third task was to initiate an emergency call via a big and red push button in form of a clickable mockup in the smartphone screen (*active*). The mockups of this General User Interface (GUI) based feature were perceived as being easy to understand and use.

The medication intake reminder service was accessed either via the Voice User Interface (VUI) by using a speech-command or by selecting the corresponding button on the smartphone. The concept of the medication intake reminder was presented to users who were asked how they would preferably use this service. Furthermore, users had to rate different feedback signals (Pre-recorded voice, synthesized voice, a melody, a ringing and a beep sound) to explore their preferences and which interaction modality would be suitable to affirm the medication intake to the system, e.g. speech input, or swipe out on the smartphone screen, etc.

Finally an early version of the hearing verification test was presented to participants who were enabled to calibrate the volume of the hearing glasses by using the available software. User feedback underlined the advantage of performing this test at home, so that they do not need to leave the house or visit a doctor. Results were converted into technical requirements, implemented and presented in the next section.

# 3 SYSTEM DEVELOPMENT

The services described in the introduction are those currently implemented. More services will be added in the future (such as health, fitness, and affective assistant). Each of the mentioned services are using either hearing aid embedded sensors (see section 3.1) or ambient information. This low level environmental data is transformed and enriched by a platform with metadata and stored at a triplestore. To fullfill this tasks the openAAL platform was created. It is a Context Management platform which offers different interfaces for data exchange between every components. Every AHEAD service participating the AHEAD system is connected to the platform during the whole lifecycle of the AHEAD system. Depending the involved components, there are different interfaces to communicate with the platform. The following list shows the different components participating in the AHEAD system.

- Wearable devices like the hearing glasses from Bruckhoff and the C-SPO1 ear sensor from cosinuss, which are measuring vital parameters like the heartrate. These sensors are connected via Bluetooth to a mobile phone running the AHEAD APP. This APP transforms the data into a Extensible Markup Language (XML) message and sends it to the platform.
- AHEAD services, fullfilling the services to assist the enduser in his/her daily life.
- escos connector for integrating, measuring and controling the devices at home of the AHEAD system enduser.

Each of this interfaces and the processing of the data inbetween will be described later in this paper. The openAAL platform is like the described services not yet fully implemented but will be extended during the AHEAD project with further functionalities. Currently the interfaces and the transformation of the data into higher level data are developed. But a Context Management platform needs more than just the preprocessing and storeing of data.

## 3.1 Hardware Components

As exemplified on Figure 1, the AHEAD system is composed by various devices connected together: the openAAL platform (see section 3.2), a smartphone, a hearing instrument (either eyeglasses of behind the hear system), hearing verification tools, and embedded sensors that are now presented into more details.

### 3.1.1 Mobile Phone

The smartphone used for the prototype is a Nexus 5 which runs an Android operating system (version 4.4.4, released on June 2014, API 20). The Nexus 5 is powered by a 2.26 GHz quad-core Snapdragon 800 processor with 2 GB of RAM. Since the android version is higher than 4.3 the smartphone supports Bluetooth Low Energy (BLE) which is used to connect and exchange data with Cosinuss physiological sensors and Bruckhoff audio module. In addition the smartphone interoperates with the openAAL platform and AHEAD services. The AHEAD mobile applications has an orchestrator responsible of managing (1) background services (such as localization Service, SpeechToText Service, TextToSpeech Service, Cosinuss Service (to received Heart Rate and accelerometric values), OpenAAL Service and (2) the mobile Graphical User Interface (GUI, section 3.4.1).

### 3.1.2 Hearing Instrument

The Figure 2 shows Bruckhoff hearing aid la belle with a RIC system.


Figure 2: (left) Bruckhoff hearing aid la belle with a RIC system that is mounted on regular eyeglasses. (Right) Cosinuss hearing aid with embedded physiological sensors.

This means the speaker is in the ear canal and is placed in front of the ear drum (tympanum). The RIC system can be used for an open fitting, without an ear mould in the ear. This is a good solution for a person with normal hearing, because they will have the sensation of not wearing anything in the ear. This is also suitable for people with mild or moderate hearing loss.

### 3.1.3 Hearing Verification Tools

Before the start of AHEAD project a verification procedure was performed as follow: a laptop runs the hearing test software. A special hardware unit (audiometer) is producing the verification sounds for the hearing tests. The test stimulus is presented to the hearing-impaired person using inserts, a headset or a free field speaker. For the AHEAD project the hearing verification hardware (the laptop and the audiometer) will be replaced with a mobile device (smartphone) and a wireless Bluetooth speaker. In this upcoming new configuration, the auditory verification test will be performed at home without the need for the person to go to a professional office.

### 3.1.4 Embedded Sensors

The embedded sensors (oxygen saturation ($SpO_2$), skin temperature) are integrated in the silicon cap (Figure 2, right), that is positioned in the user's ear canal. In addition a 3D accelerometer is located on the PCB near the Microcontroller.

To measure $SpO_2$, two different light sources are needed: one red LED and an infrared. The LEDs blinks alternatively and a photodiode detects the out coming light. The proportion of the constant values of both light intensities and the modulated values, allows the $SpO_2$ estimation. For this, the Lambert-Beer law and some simplifications are used.

The heart rate (HR) is measured optically. The light of a LED is sent into the tissue and a photo diode will measure the intensity of the out coming light. This light is modulated by the blood, which is pumped from the heart. Due to the blood volume variation, the heart rate can be detected.

The skin temperature is measured by a thermistor which changes its resistance together with the temperature. The resistance is measured from an analog-digital-converter, which has a very high resolution (24bits).

In addition an accelerometer has been added. This data is processed by the smartphone which extracts information related to the user physical activity which will serve for the fitness assistant.

## 3.2 System Architecture

This section will deal with the requirements and the architecture of the openAAL platform and the participating services. It will be pointed out, which functionalities the platform has to provide considering the AHEAD services and their requirements. The openAAL platform was developed at FZI research centre as AAL research platform. Further openAAL is a distribution of the universAAL middleware. The universAAL architecture is an EU research project funded by the European community’s seventh framework program. The distribution is developed in several releases. It is a context management middleware basically for providing the communication infrastructure between devices and AHEAD services. The goals are to integrate and support different hardware devices and to collect and transform environmental data, measured by sensors into context information for the AHEAD services. It consists of different components, executing different tasks. The scenarios in AHEAD require the ability of the platform to communicate with different kind of devices from different manufacturers. Besides of this the introduced services like the Emergency Call need real time communication, because every lost second can be important to save the life of an affected person. The modularity of the architecture allows it to extend the platform with further features and functions. A high number of users shall be able to use the services running in the AHEAD system.

These services are written in different programming languages. Various protocols are used by different participating devices. So scalability, interoperability, real time capability and standardization are also requirements of the platform. The environmental sensors and the interactions of the user with the wearable devices and the UIs supply a lot of valuable data. This data is used by the AHEAD services to serve recommendations and information appropriate to the situation and context of the user. Further the platform has to decide, which service is the right service in the right moment and the right situation. To achieve this task, the context of the end user has to be pre-processed and evaluated. Considering these challenges the platform has to accomplish basically three tasks. First collect sensor data and check if data are valid. Second, pre-process and aggregate this data to common machine readable instances representing the real world environment of the end user. Third, estimate from the data what are the needs of the end user based on contextual and behavioural information.

Figure 3 shows the components of the AHEAD system. One component is the AAL space containing sensors and actuators. Usually this AAL space is the sensorised environment (e.g. the home) of an end-user. The terms end-user and assisted person are used in this context synonymously. Beside we have two wearable devices: the hearing aid and its embedded physiological sensors. These devices cannot exchange data directly with the openAAL platform but are communicating via Bluetooth profiles with the Android mobile phone of the end user running the AHEAD application.

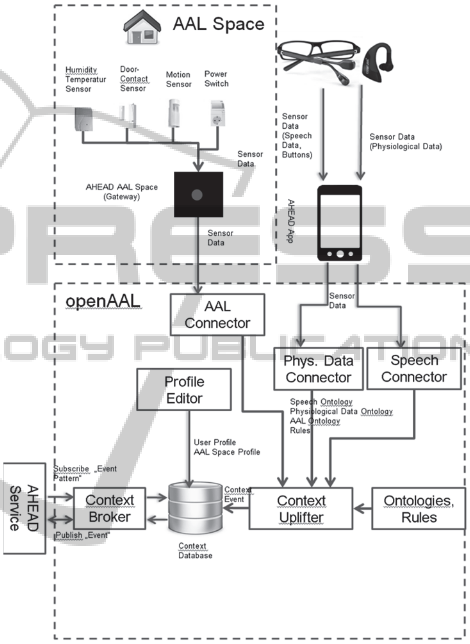


Figure 3: AHEAD system components.

This AHEAD mobile application transforms the received data into a predefined XML messages and transmits them to the openAAL platform. This XML messages contain basically Metadata containing: user authorization data, the functionalities (and associated software services) the user is interested in, measured values by the given sensors. There are different messages that the mobile phone can send to the openAAL platform. For example if the user requests a service using a voice command then an XML message for “speech commands” will be sent to the platform. Such xml message contains a timestamp, login data (username, password, id, email address…) for authorizing the user at the platform and the main part: the message node. It has several attributes which define both the type and content of the message. Sensor data (e.g. heart rate) are transferred from the mobile to the openAAL with a different xml structure “data device”. The communication between the mobile phone and the openAAL platform is set up through a Web Socket connection. Web Socket was chosen because it allows a full duplex communication, staying, open as long as needed. In addition it allows to manage several simultaneous connections, creating a new session every time a new client connects to the platform. The mobile phone connects as a client to the Connectors (Figure 3) and sends the transformed data. Every message type has an appropriate Connector at the platform responsible for the pre-processing and transformation of the retrieved data. This transformed data is sent to the Context Up lifter which enriches the data with Metadata and transforms it into Ontology instances. These Ontology instances are saved into a Triple Store which contains all data about the environmental events and provides in this way a history of the contextual states. This history can be requested by an AHEAD service through appropriate queries. Beside this, the platform delivers with every occurring event, and after a mapping process, the appropriate ontology instances to the Context Broker. The Broker parses the service registry and sends to the fitting service the appropriate information. The pre-condition is, that the service has registered itself to the Context Broker and implements the interfaces pretended by the Broker. If an AHEAD service is running on a different platform implemented in a different programming language a remote communication is taking place. The Broker and the appropriate AHEAD service are generating JavaScript Object Notation (JSON) messages to communicate.

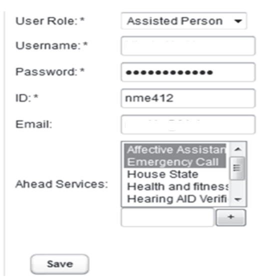


Figure 4: Web interface of the AHEAD system for adding new user profiles.

The Profile Editor is a Web interface for introducing new end users to the AHEAD system. Figure 4 shows the web view for adding new end users to the AHEAD system. Each user is profiled by its authorization data, the services he or she wants to benefit (e.g. emergency calls, medication reminders, auditory verification test, …). When this information introduced for a particular user, only the requested services will be activated for him/her.

Currently the mentioned components are implemented. Further components to personalize the AHEAD services to the needs of the end user will be developed and tested in the framework of the AHEAD project. It is planned to extend the context management functionality with machine learning algorithms and reasoning techniques on top of the AHEAD ontologies. The AHEAD ontology is modelling the context of the user environment, the user itself and the participating services. This ontology was developed to make it possible to reason about the current situation of the environment of the end user and to support in this way knowledge about the AHEAD domain. Ontologies make it possible for services and applications to "understand" each other. Precondition is that the appropriate Ontology has to be available in the web to be every time retrievable by the appropriate application. By publishing derived Ontologies by the AHEAD services we can extend the knowledge of the AHEAD system. A further goal is to give to services the possibility to make semantic requests when looking for information and knowledge about the AHEAD domain.

It is quite conceivable to introduce into the AHEAD system a learning mode, during which the system learns out of the behavior, the activities, preferences and needs of the end user in order to have the most appropriate level of assistance.

## 3.3 Implementation and Evaluation of the Services

This section describes briefly the results of the first Remote Integration Workshops (November 2014 and March 2015), where we have established the integration of three main components of the AHEAD system: the end-user with its mobile phone, hearing aid and embedded physiological sensors, the openAAL platform and the desktop of a doctor setting up medication reminders (Figure 1) through a web interface (see section 3.4.2). The purposes of the tests were to verify the authentication procedure, the flow of information between the three components, and the business logic.

### 3.3.1 Emergency Triggered by Vital Signs

First we tested the system with only one user connected to the AHEAD system. The user was wearing the in-the-hear physiological sensor (Figure 2-right) connected to a smartphone. Measurements were received periodically (every 2 seconds) by the smartphone and automatically forwarded to openAAL platform which also redirected them to the “Rules and Notifications management” service. The test was made with simple rules (for instance, if Heart Rate > 60 then make an emergency phone call). The “Rules and Notifications management” service successfully sent back to the openAAL platform such notification when rules were met. Finally the openAAL properly processed this notification and redirected it to the smartphone which was able to trigger automatically the emergency call. Secondly we tested how the whole system would react with the transfer of measurements coming from two different end users with different smartphones. Two emergency phone calls were automatically triggered demonstrating that the bidirectional communication tested with two end users, two smartphones and different sensors was successfully accomplished (Barralon, 2014).

#### 3.3.2 Medication Reminders

The Medication Reminders aimed at evaluating if reminders were properly set and properly deliver to the correct end-user (mobile phone). From a desktop computer a fake doctor introduced a list of reminders. This list was formatted by a AHEAD service (running outside the openAAL platform) and sent to the openAAL platform which was in charge to redirect the specific medication reminder to the correct smartphone, at the predefined day and time. The execution of such scenario was successfully achieved. In addition, the current implementation of the AHEAD reminder service allows to specify which modality (visual popup message, Figure 5-right, or synthetized audio message) is used to conveyed the message. Both modalities worked. The time difference between the setup of the reminder and its delivery was considered as short (less than few seconds) by the tester.

### 3.4 Graphical User Interfaces

#### 3.4.1 Smartphone

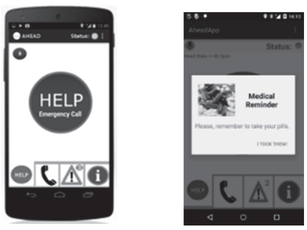


Figure 5: Main activity (left); Reminder popup (right).

Figure 5 is presenting two screenshot of the AHEAD mobile application. On the left, the main screen is shown with the four menus: emergency, phone call, list of warnings/reminders, and various information (e.g. weather forecast). On the right hand side a visual medication reminder popup is shown.

#### 3.4.2 Rules and Notifications Management Service

The Rules and Notifications management service is a web application, composed by a web service, a SQL (Structured Query Language) Server Database and a web socket client. The web service is the responsible to access and to execute the stored procedures created in the database which are used to manipulate (insert, delete or modify) data into the database. The web socket client is the responsible to grant the bidirectional communication with the OpenAAL platform. The aim of this service is to allow caregivers and medical professionals to manage rules, notifications and activities to be performed (in the case of the affective assistant rules) according to a set of pre-defined and personalized rules (Figure 6) based on individual changes in the end users’ health status and/or their environment.

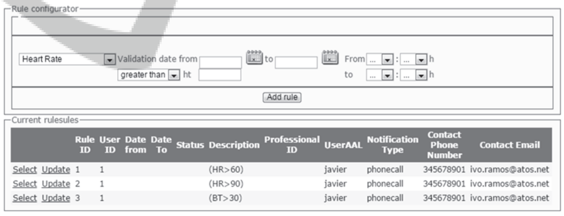


Figure 6: Personal Alarms configuration.

These notifications, in turn, will facilitate the day-by-day work of medical professionals, as well as formal and informal caregivers, in addition to provide support to users related to their individual health status. The system is based on a closed cycle that involves end users, medical professionals and the informal caregivers. It combines the orchestration of services with an underlying efficient networked-based event management solution.

The selection of a particular rule it will open the “Notification Configuration” webpage (not shown). This page allows the configuration of the type of notification associated to the personal alarm rule (by email, SMS or phone call).

There is also an Affective Assistant configuration page, that proposes the best suitable daily activity or suggests a new action (e.g. meet a friend, go for a walk, take medications, and perform an aerobic activity) based on the analysis of the vital signs parameters determining the current emotional state of the user. If a sufficiently lasting low emotional state situation is detected the user will be instructed to do an alternative activity.

The “Medication Reminder” configuration page allows the caregiver and the medical professional configure the medication reminders for the end user. It is also possible to configure the time frequencies of the reminders: the starting intake hour, the definition of the intake period (for instance, every four hours) and the starting and ending date where the reminder is considered active (Figure 7).

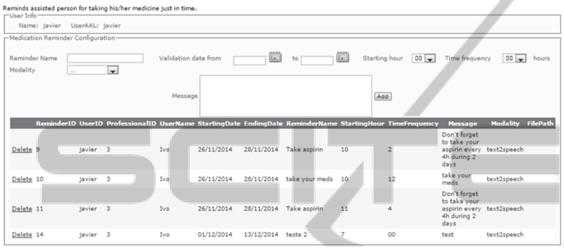


Figure 7: Medication Reminders configuration.

It is also the possible to visualize all medication reminders for all users. A button “Send to OpenAAL” will update the list into the openAAL platform. The communication is made between the web socket server and a web socket client, using a JSON format message which contains inside the list of reminders in a XML (eXtensible Markup Language) format (Wulf, 2014).

### 3.5 Voice User Interface

Beside the graphical interfaces presented earlier the user is interacting with the AHEAD system by voice commands (e.g. “help”, “emergency”, “call Peter”) and audio feedbacks either using pre-recorded audio files or synthetized voice messages (“It’s time to take your medication”). During the second lab trial of AHEAD user expressed a preference in using pre-recorder messages (by themselves or relatives) than synthetized voices.

## 4 CONCLUSION AND OUTLOOK

Within user centred design the development of the first service components and interaction modalities of the AHEAD system as presented in this work has been achieved: the emergency call via voice command and push button as well as an early prototype of the Audiometry Verification test were evaluated with end users in a first lab study. The second study involving elderly users in an upcoming task-based lab evaluation will aim to gathering feedback on user experience and perceived interaction quality of selected advanced multimodal AHEAD components namely the Activity Tracking module, Medication Reminder and Audiometry Verification Test which will be used on a smartphone application. On the basis of the gathered user feedback the system components will be improved towards enhanced interaction quality for hearing impaired older users. Remaining services are currently under development and will become the center of interest in a third evaluation study in the lab which will finally pave the way for the deployment of the fully integrated AHEAD system in a long term field trial to take place by end of 2015.



## ACKNOWLEDGEMENTS

The research presented in this paper is conducted as part of the AHEAD project (AAL-2012-2-167), which is partially funded by the European Ambient Assisted Living Joint Programme and the National Funding Agencies from Austria, Denmark, Germany and Spain. Iñigo Dorronsoro, Javier Camarena, Johannes Kreuzer, Olaf Grumptmann and Jürgen Braun have also strongly contributed to the hardware and software developments of all components presented in this paper.

## REFERENCES

Phonak 2015. http://www.phonak.com/com/b2c/en/products/ wireless-accessories/products/compilot/hearing-aid-accessory.html.

Starkey 2015. http://www.starkey.com/hearing-aids/surflink-wireless-accessories/surflink-mobile.

ASSISTANT 2012-2015 http://www.aal-assistant.eu/

HearMeFeelMe 2012-2015. http://www.aal-europe.eu/projects/hear-me-feel-me/

Rashid, A., Wulf, L., Garschall, M., 2014. *Augmented Hearing for elderly people – User Requirements and Use Cases.* 4. AAL-Workshop auf der Mensch & Computer 2014 „Senioren interaktiv unterwegs – (Kooperations-) Systeme gestalten“.

Barralon, P, Camarena, J., Dorronsoro, I., Merkle, N., Ramos, I., Kreuzer, J., Grumptmann, O. 2014. AHEAD project *Deliverable D3-3 First integrated prototype.*

Wulf, L., Barralon, P., Kreuzer, J., Perez, M., Ramos, I., 2014. AHEAD project *Deliverable D3-2 - Low-fi Interface Prototypes.*