Wireless smart environment in Ambient Assisted Living for people that suffer from cognitive disabilities

Sistema inalámbrico inteligente de apoyo a personas que sufren de discapacidad cognitiva

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RESUMEN

El desarrollo actual, en comunicaciones inalámbricas y en tecnología de la información, ha abierto la posibilidad de crear soluciones innovadoras que pueden contribuir a mejorar la calidad de vida de personas con algún grado de discapacidad física o cognitiva. Este artículo presenta el desarrollo de una innovadora solución de asistencia móvil basada en biosensores, tales como electroencefalogramas (EEG), medidores de frecuencia cardiaca (HR) y de la conductancia de la piel (SC), que ayuda a personas que sufren de discapacidad cognitiva a lograr equilibrio y expresar sus emociones o estados de ánimo. Mediante el monitoreo de estos estados se puede mejorar su comunicación con otras personas, la ejecución de tareas y también los patrones de sueño.

Palabras clave: Ambient Assisted Living (AAL), comunicaciones móviles, discapacidad cognitiva, estados emocionales y/o mentales, estimulación mediante luz o sonido, síndrome de Down, autismo.

ABSTRACT

The development in wireless communication and information technologies has led to the possibility of creating innovative solutions that can contribute to the improvement in life quality for people with some impairment, physical or cognitive. This article presents the development of an innovative mobile assistive solution based on biosensors, such as electroencephalogram (EEG), heart rate (HR) and skin conductance (SC). This solution could help people that suffer from cognitive disabilities to balance, express and monitor their emotions and/or mental states, improving communication, task performance and sleep patterns.

Keywords: Ambient Assisted Living (AAL), mobile communication, cognitive disabilities, emotions and/or mental state, light and sound stimuli, Down syndrome, autism.

INTRODUCTION

The combination of technology and health sciences is a strong and innovative field where there are many opportunities for researchers to develop medical devices to assist individuals with motor and /or cognitive disabilities.

Nowadays, sensors and amplifiers that measure emotions and/or mental states such as electroencephalogram (EEG), heart rate, skin conductance and other physiological signals, are only used in laboratories. Their low cost and world-wide availability permits the development of small wireless devices for use on a daily basis in homes

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or care institutions, allowing anyone to monitor signals by wearing non-invasive sensors.

Furthermore, the unprecedented development in wireless communication and information technologies gives rise to the possibility of creating innovative solutions that can contribute to the improvement in the quality of life for elderly people and individuals suffering from cognitive and motor disabilities, e.g. Autism, Alzheimer, Down syndrome, strokes, amyotrophic Lateral Sclerosis (ALS) and Attention deficit-hyperactivity disorder (ADHD) etc.

Ambient Assisted Living (AAL) plays an important role in this area by using information communication technologies to create pioneering services. According to Horst Steg [1] AAL conception is:

AAL aims to prolongate the time people can live in a decent way in their home by increasing their autonomy and self-confidence, the discharge of monotonously everyday activities, to monitor and care for elderly people or ill person, to enhance the security and to save resources.

AAL solutions emphasize in autonomy enhancement and emergency assistance where the last one can be divided in detection, prediction and prevention. Some of the promising fields for AAL are disease management, ambient intelligence for specific target groups and maintaining the wellness of disabled people.

Despite the lower price and accessibility of technology for developing innovative services, one of the main barriers and challenges for AAL services and products designed for people that suffer from cognitive and motor disabilities is the acceptance of new technology.

According to the analyses and technical notes from the 2010 Revision of the World Population Prospects, the demographic change will produce more and more people over 65 years old [2]. This report shows that the amount people over 65 years old in 2050 and in areas where there are over 100.000 citizens could almost double that of the population measured in 2010 in the majority of developed countries. This social change may cause dramatic effects on public and private health care leading to more people being at high-risk of developing diseases that lead to cognitive and/or motor disabilities. Individuals of advanced age and/or with cognitive or motor disabilities would greatly benefit from smart environments, which could provide augmentative communication, transportation, and/or devices control. Such environments would provide more autonomy, independence, better life style, security and connection to the society [3].

This demographic change increases demand for care, especially in disable people who live independently or in care institutions. On a daily basis they face frustration, sadness and anger due to memory problems or difficulty in communicating their emotions. In addition to that, costs for the society and the care provider are growing, which may lead to problems providing health care and technological resources in the future.

In order to enhance the wellbeing in patients that suffer from motor and/or cognitive disabilities it is necessary to use a system which helps to monitor, express and balance emotions or mental states, improve communication, task performance and sleep patterns. These challenges are crucial for people that suffer from cognitive disabilities like Autism and Down syndrome because they need to communicate their emotions when they are frustrated, anxious or stressed.

This paper presents the development of a smart assistive prototype called Ambient, which is based on using lights and sounds as stimuli controlled through physiological signals recorded using wireless biosensors. It helps people with cognitive disabilities to balance their mental state, improve task performance and sleep patterns.

According to Stefan Koelsch [4], Arvid Skjerve [5] and I. Knez [6], music and artificial light affects our internal clock, mental alertness and mood. Their studies showed that it is possible to modify people's mental state by presenting them with auditory and visual stimuli, in the form of music and light, under certain conditions.

This paper answers the following questions:

1. What kind of sensor hardware combinations are available and suitable to record patterns in people's emotions and/or mental states and is it possible to design such a wireless system?

2. Is it possible to modify mental state by using light and sound as stimuli?
3. What are the user needs of people with a cognitive disability?

The rest of the paper is structured as follows: section BACKGROUND introduces the theory of light and sound as therapy as well as the way to detect, recognize and classify emotions or mental states. Section RELATED WORK provides an overview of some incidental work. In section PROTOTYPE the design and architecture of Ambient is presented. Under the section EXPERIMENT RESULTS AND THRESHOLD EVALUATION a conducted test of the system and its results are presented. The last section discusses further development of the system and further research.

The Figure 1 shows the main actor in a house where Ambient is installed. He wears biosensors on the head and wrist that communicate wirelessly with a Tablet PC, which then communicates with the light and sound system and reacts according to the person's mental state.

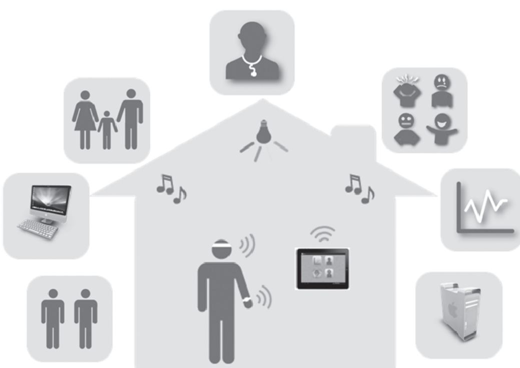

Figure 1. Ambient general overview.

In order to answer the fore mentioned questions, different methodologies were used, such as Ethnographical observation and interviews with the main stakeholders regarding the requirements of the system. The interviews were done before the development of the prototype, in order to find the user's needs and knowledge in the AAL area. A second round of interviews was done after the development of the prototype, aiming to get feedback from the second main actors, caretakers.

Finally, several tests with potential end-users were completed using different tools such as Stroop effects and brain band monitors, as well as special light and sound conditions in order to measure and stimulate the mental state of the participants, and to find a threshold that makes the prototype respond accurately.

BACKGROUND

A. Light and Sound

Natural light and sound play an essential role in human health. They affect people's physical and mental wellbeing. The natural light and artificial lighting in environments influence our emotional states, changing our mood and behaviour.

Natural light is considered a regulator of circadian rhythms, our internal clock. Several studies have shown that artificial light with a defined intensity can affect our internal clock, influencing our sleep patterns, body temperature and mental alertness [7-8].

A report published in 2003 by Boyce, describes how people's moods are affected by different types of lighting conditions, both natural and artificial [9]. It also mentions that for the same lighting conditions, perception and impacts on mood could vary across people.

Others studies examined the impact of light from natural or artificial sources on people's mood and task performance. In one such study by Igor Netz [6] in 1995 the results showed that some type of artificial lights can induce some negative effect on people's mood when trying to accomplish some tasks. Another type of light induced positive effects and helped the some participants in the study to accomplish tasks better. The research was carried out on people without cognitive disabilities and the experiment revealed mood congruent effects on different genders and ages.

In 2005 Nadeen Abbas [10] reported that light intensity and colour changes our Heart rate and the influence of this stimulus is subject dependent. This research was conducted by exposing subjects to different colours and light conditions during 110 minutes, but only recorded the last 2 minutes.

In the other hand Sound or Musical stimuli seems to activate different areas in the brain associated to emotional behaviour as shown in the studies written by V. Menon and Stefan Koelsch [11]. Koelsch analysed how pleasant and unpleasant music can be to induce some emotions. He found that unpleasant music activate some body organs like hippocampus and temporal lobe. In the other hand pleasant music activates e.g. the inferior frontal gyrus and anterior superior insula. In neurological setting, music therapy has been used in patients with dementia having positives effects on behavioural alterations and emotional and cognitive deficits [12].

RELATED WORK

There are many studies and assistive solutions for people that suffer from physical or cognitive disabilities. The majority of them are focused in assisting people to live longer in their preferred environment and a few of them in mobile monitoring. These systems can be divided into three identifiable solutions, namely emergency, autonomy and comfort solutions.

There are several benefits of these systems. These include remote monitoring, which allows fast detection of emergency conditions, like a heart attack. For instance, Mobecs [13] describes a project which focuses on detecting home or outdoors emergency situations for people with mental or physicals disabilities. It uses acceleration and motion sensors, GPS modules, microphones and cameras integrated in smartphones as well as in-clothing and accessories such as belts and wristwatches. Another example is QuietCare [14], which monitors the activity patterns of residents and sends potential urgent situations to caretakers. It uses motion sensors installed in a room which are interconnected using Zigbee as communication protocol.

Other solutions examples are Curaga [15] and Kinempt [16], where different technologies, like QR code and Kinect are used, respectively, in order to help people with mental disorders to perform tasks independently, by using electronic devices for task support, or simply for finding the way to move inside their environment.

The prototype presented in this article centres in a portable wireless mobile system for monitoring biosignals in real-time and the use of light and sound as therapy. During the research period it was not found any project with the characteristics of the system presented in this paper. Nevertheless, the last part of this section describes two projects that are similar to Ambient, in the sense of regarding wearable wireless bio-sensors, real-time monitoring with mobile devices and data analysis and storage.

The first one is Code Blue project [17], which is a wireless communication infrastructure for critical care environments. This project started in 2004 and it employs ad hoc networks of motes with sensors such as oximeter (SPO2), electrocardiogram (ECG), electromyogram (EMG) and motion sensors, in order to give a response in pre-hospital and in-hospital emergency care. The second is MobiHealth (Mobile [18]), which uses a wearable computer allowing to receive personalized feedback from a care professional anytime and anywhere. It uses third party sensor systems (ECG, EMG, SpO2, respiration, hear rate, temperature and plethysmogram) through Bluetooth standard interface.

PROTOTYPE

B. Methodologies and experiment

The methodologies described in this section were aimed at gathering valuable data that will be useful for the development of this solution. The methodologies can be organized as follows:

- Ethnographical observation
- Interviews
- Experiment and data collection

1) Ethnographical observation

When developing a user centric service it is important to capture the user's requirements in order to improve the design of the solution. The requirements analysis is a long process, where some sociological and psychological skills are involved. This method was used three times within a two week period, and it helped in the understanding of technology usage and limitations among a population with a different type of cognitive disabilities and their limitations upon its use.

2) Interviews

The interviews were divided in two steps. The initial interviews were with key actors of the project, such as Social Development Centre SUS institution [19], caretakers, professors and some companies were conducted in the early stage of the research process, to acquire deeper knowledge about AAL area and the user's needs.

The first step of this qualitative research consisted of an interview with Kasper Nizam, chief consultant at SUS where we gathered information regarding existing solutions, user requirements, challenges and limitations when introducing new technology to end users and caretakers.

Additionally two additional interviews were conducted with Dagcentret Sundbyvang [20], which is an institution for integration and rehabilitation of people that suffer from cognitive disabilities. The person interviewed was Jesper Foghmar, who is one of the caretakers in this institution and he is in charge of making workshops to his colleagues when a new technology is introduced at the institution. He also holds under his tuition a group of eight people with different type of cognitive disabilities.

The first interview with Jesper helped to learn about the structure of care institutions, the technologies used, applied methodologies and the user's needs. The second interview, which is also part of the second round of interviews, aimed to present the prototype to the caretakers in order to discuss the way to perform the tests and to analyse the acceptance to this type of technology, as well as to get feedback regarding the system in overall and in particular about the graphical user interface.

The second round of interviews was conducted during the evaluation of the prototype and it aimed to revisit the requirements gathered in the initial interviews and to define future steps for a second prototype.

Most of the caretakers got fairly interested in the idea. Some of them asked about in which scenarios this system could be used, some of them did not see so much advantages if using this system at their working place and some of them even stayed voluntarily longer time after the meeting time schedule, only because they wanted to try a bit further the system and get tested wearing an EEG Brainband.

3) Experiment

In order to validate the prototype developed, a system threshold was determined to evaluate if physiological changes were presented by exposure of light and sound. A controlled experiment was conducted after the development of the prototype. The experiment was carried out in a lab located at Aalborg University in Copenhagen, where different subjects were evaluated with an EEG Brainband placed on a person's head (Figure 2).

The data gathered during the experiment helped to ascertain a more accurate system by comparing healthy subjects from the ones with cognitive disabilities.

a) Subjects

The numbers of test subjects were limited to ten people of varying gender, age, mental disability and background. The subjects numbered 1 to 5 are in their thirties and with no mental disability diagnosed. These subjects are studying for practicing varying jobs, such as engineering in information technology, informatics and design.

The subjects 1, 2 and 3 were male and subjects 4 and 5 were female.

The subjects 6 to 10 are in their twenties with mental disabilities with 2 Down syndrome and 3 Autism patients. These subjects assisted daily to a care institution and all of them are males.

The subjects were tested by analyzing their mental states while inducing attention (Stroop effect [21]) and meditation (music and light). The light used during the test consisted in RGB LEDs set in a special room, controlled by Arduino. Some of the colours like blue and red represented meditation and concentration respectively. Additionally the same colour was displayed in computer PC screen for helping to radiate the colour in the entire room.

The subjects were divided in two groups, one with, and the other without cognitive disabilities. The subjects were sat comfortably in a chair wearing Myndplay Brainband [22] on their heads. To enhance experimental control, part of the study was conducted with one participant at a time and the test was lead in a room of nine square meters. The Brainband was placed over the pre-frontal cortex with the electrodes placed two centimeter above the eyebrow (Figure 2).

Figure 2. Electrodes position.

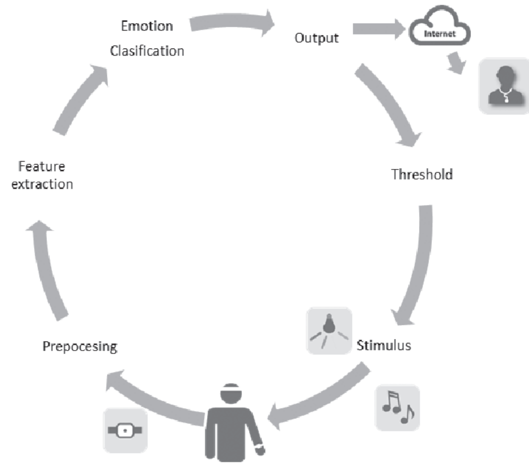

Figure 3. Diagram presents the data flow through various components.

4) Test protocol and stimuli selection

Attention Test: The Attention Test consisted of designing two different tasks to be executed by individuals suffering from cognitive disabilities and another task to be executed by individuals not having cognitive disabilities.

The first task, as mentioned before, was using a tool called the Stroop effect which requires attention when executing it. This test consists in saying the name of a colour written in a paper which is painted by another colour (e.g. the word blue was displayed in red). The second task was to play the classic game called find 'Waldo'. For the subject with cognitive disabilities they were required to look at a book of interest.

Meditation Test: The Meditation Test consisted in playing some relaxation music created by a Danish composer Niels Eje [23] and using blue light colour. The test duration was 7 minutes, same length as the song.

Architecture

Ambient prototype is a system which is composed of five elements. These elements (Figure 4) are: Myndplay EEG Brainband responsible of detecting brain waves, Arduino BT in charge of controlling the light system, a front-end located in an Asus Tablet PC with android 4.1(Jelly Bean) responsible of the interaction with the user, a data base located locally in the Tablet PC and a Jambox speaker in charge of emitting sound when receiving signals from the Tablet PC. All these devices communicated using Bluetooth protocol within a range of 10 meters. The ideal prototype was thought to communicate using Bluetooth Low Energy due to its characteristics in range and power consumption.

This diagram (Figure 3) presents the data flow through various components and it starts with the user wearing sensors like EEG, Heart Rate and Skin Conductance. Following the arrows direction, all the data gathered by the sensors is processed and filtered. After the emotional state is extracted, classified and finally uploaded to a data base where the physician or caretaker can access and monitor it. Also a threshold is set in order to warn a caregiver and to make the environment react with a visual and auditive stimulus.

It is important to note that the threshold programmed on the prototype was set according to total average probability values (Table 2) obtained from the experiment.

The communication flow in the system architecture (Figure 4) starts from the Brainband sending the signal to the Tablet PC. When some values over a threshold are detected, a signal is sent to the light and sound system.

The EEG Myndplay Brainband is responsible for brain waves data transmission. The Asus Tablet PC is running the front-end part and back-end for data exchange with a SQLite database.

5) State Machine and Flow diagram

The state machine (Figure 5) describes the three modes of the system and the threshold values needed to move from one mode to the other. The system starts up in Normal mode after establishing

Figure 4. System architecture diagram.

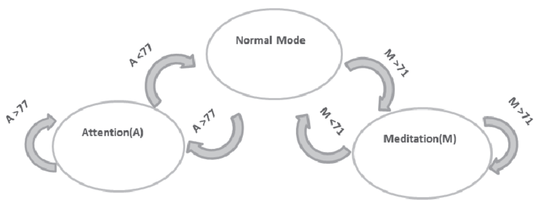

Figure 5. Diagrammatic representation that illustrates the sequence of operations of the prototype solution.

connection with the sensors devices. In Normal Mode, if the values of attention increase above the threshold according to the eSense [22] scale (Table 1), the system enters in attention mode and the light and sound corresponding to it start. If the values recorded after the system has been in attention mode decreases below the threshold, the system goes back to Normal Mode of relaxation.

The same thing happens if the values of Meditation are above or below the threshold, then the system will emits the light and plays the sound corresponding to the mental state detected.

The system starts by detecting the devices placed in a person's room according to the Bluetooth protocol. If the devices are detected, so they pair up and the prototype gets in Normal mode, otherwise it attempts to connect again.

C. Software Design and implementation

1) Communication between front-end and light system

The communication is only one-way, from Tablet PC to Arduino. The block marked in light yellow (Figure 6) stands for a third party application used in this project. This application is called Amarino [24] and it is used to establish a communication between the two devices. It helped to make fast prototyping and it does not interfere with the application developed in android because it runs in the background.

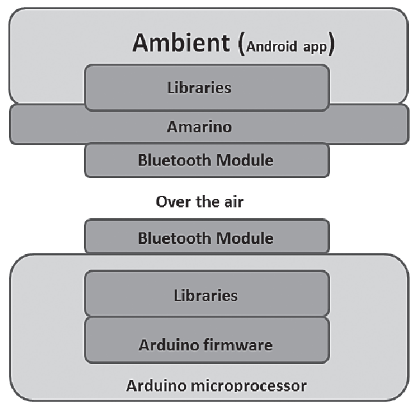

Figure 6. Architecture communication between Ambient Android Application and Arduino.

The Arduino is in charge of processing all messages coming from the Ambient android app and sends signals via serial communication in order to execute an action. This action of fading colours is done by using the pulse width modulation (PWM) feature of the microprocessor.

2) Communication between EEG Brainband and Ambient application

This section shows the architecture communication between Myndplay Brainband and Ambient app (Figure 7). The brain signals are detected by the electrode and data is filtered and processed in a module which contains the ThinkGear microprocessor. The data processed can be send as raw data or eSense, which gives values from 0 to 100. The data is then encoded within packets and then transmits over Bluetooth as a serial stream.

D. Front-end (GUI)

The Graphical User Interface was implemented using android native language, it means it was written in Java and the user interfaces in XML. The application was programmed for Android 4.1 and up, using API 16. The background of the application uses a simple blue colour that is not very intrusive

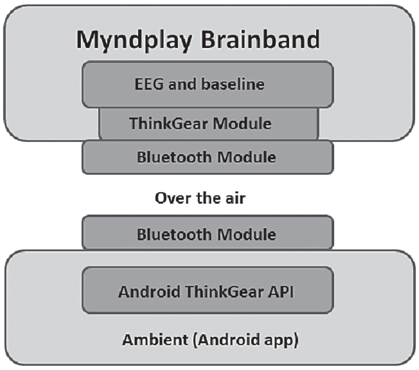

Figure 7. Architecture Communication Between Myndplay Brainband and Ambient Application.

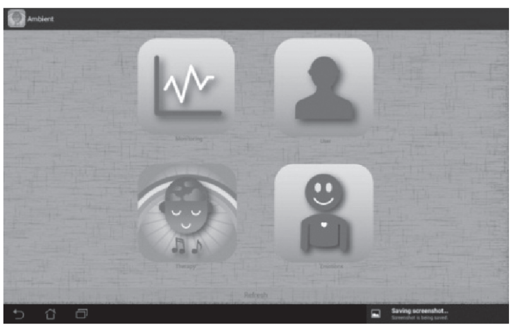

Figure 8. Screen shot of the Main Menu Screen. The user has four icons respresenting the main features of this application which are User, Monitoring, Therapy and Emotions.

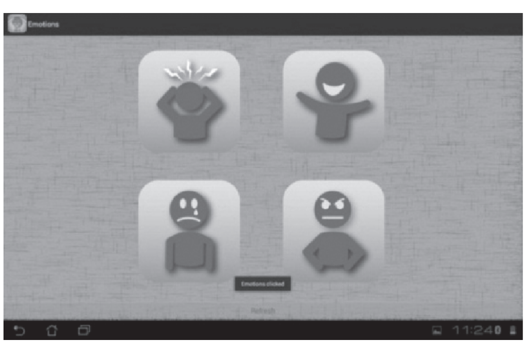

Figure 9. Screen shot of the emotion screen page.

so not to attract the eyes of the user away from the icons. The icons are designed using friendly images trying to represent the intended action making easy to surf through the application.

The idea of this design (Figure 8 and Figure 9) was to keep the GUI as simple as possible following some of the design consideration like the type of user and Ten Usability Heuristics", created by the usability consultant Jakob Nielsen [25].

EXPERIMENT RESULTS AND THRESHOLD EVALUATION

E. Measuring Attention and Mediation Values

The brain signals measured with the Brainband are processed by the Myndplay software, and the algorithm eSense is used for this purpose (see Table 8), which outputs two values that represent the probabilities of the processed brain signals corresponding to either attention or meditation mental states. The eSense values range is from 0 to 100 as is shown in the Table 1.

Table 1. eSense NeuroSky protocol Scale.

eSense values	Strongly Lowered	Reduced	Neutral	Slightly	Elevate
Meditation (Vm)	0-20	20-40	40-60	60-80	80-100
Attention(Va)	0-20	20-40	40-60	60-80	80-100
Blinking	0	–	–	–	255

For analyzing and simulating the values of attention and meditation during the time, it was Myndplay software, OriginPro [26], and Matlab that was used

In Figure 10 the blue trace represents the mediation state and the red trace the attention state. This plot shows that under the mediation test using music, the values of mediation are higher than the values of attention at several periods of time. This is true for most subjects according to the measurements obtained. Figure 10 shows these values obtained from the EEG signals recorded under the meditation test for a representative subject.

F. Feature extraction and classification

In order to classify the EEG traces obtained in each test, a feature (called AMd) corresponding to the difference between the attention value and the meditation value was used, as shown in equation (1):

$$AMd = Va - Vm \qquad (1)$$

Equation (1) Equation for classifying the EEG traces.

Where AMd stands for Attention Meditation difference, Va is the Attention value and Vm is the meditation value.

In order to have a response from the system, then it is essential to set a threshold for the classification of the EEG signal, which must be either in attention or meditation modes. These thresholds will make the system react in real-time according to the person's mental state. In our case this threshold was set to zero, meaning:

If AMd>0 then the trial is classified as Attention, if AMd<0 then the trial is classified as meditation.

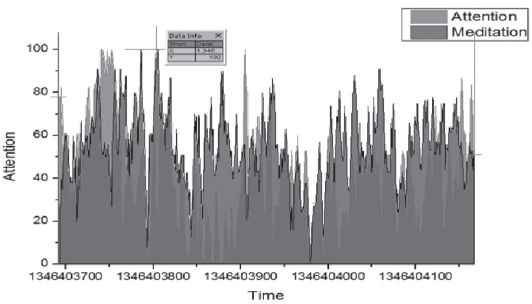

Figure 10. Attention and Meditation values during a meditation test. The Red Cross represents the maximum meditation value.

Method: As explained in the section B.3), ten volunteers were tested for this study. Five of them were healthy subjects (subject1-5)while the other five presenting cognitive disabilities (subject 6-10). The subjects were comfortable sat in a chair wearing Myndplay Brainband. The Brainband was placed in forehead two centimeter above the eyebrow. The persons were asked to execute two different tasks which would require some attention level. The light and sound system was also installed. Figure 10 shows the maximum value reached during meditation test by one of the potential end-users. This maximum value measured in this subject, corresponding to attention, it was 100.

$$CPP = \frac{number\_of\_Correctly\_Classified\_trials}{total\_number\_of\_trials} \times 100 \quad (2)$$

Equation (2) Equation for calculating the Correct Classification percentages.

The Standard Deviation of the average of the correct classification is relatively high, as shown in Table 2, this is due to the subjects 6 and 8, in the attention test, and the subjects 3 and 7, in the meditation test, did not perform as expected by getting affected by the reading and light and music respectively.

Table 2. Shows that the total average values of Attention and Meditation could overlap in some cases.

Subject/ Test	Attention Trials	Attention Trials	Meditation Trials	Meditation Trials
	Va Avg.	Vm Avg.	Va Avg.	Vm Avg.
1	81.89 ± 14.4	50.8 ± 9.2	39.801 ± 22.7	54.72 ± 17.2
2	82 ± 9.2	42.4 ± 6.7	42.87 ± 16.8	68.99 ± 20.8
3	73.5 ± 17.8	52.09 ± 20.6	68.50 ± 17.2	53.14 ± 14.2
4	41.97 ± 18.8	44.9 ± 4.1	35.62 ± 14.7	62.08 ± 19.9
5	61.88 ± 8.8	49.6 ± 6.03	60.71 ± 27.2	62.15 ± 19.5
6	40.8 ± 20.9	53.48 ± 21.03	42.1 ± 22.8	39.6 ± 14.6
7	65.2 ± 15.1	58.05 ± 10.5	58.6 ± 17.5	42.96 ± 16.2
8	53.5 ± 15.9	53.4 ± 13.4	52.47 ± 15.1	52.5 ± 11.8
9	40.89	56.87		
10	43.01	59.71		
Total average	62.61 ± 15.15	50.62 ± 11.4	50.10 ± 19.3	54.52 ± 16.8

Table 3. Correct Classification percentages (CCP).

Subject/Test	Attention(%)	Meditation(%)
1	97.96	72.59
2	100.00	80.73
3	83.87	24.08
4	51.35	80.68
5	88.89	57.14
6	34.78	51.35
7	69.2	26.18
8	48.09	48.42
Average (%)	71.77 ± 24.71	55.15 ± 22.29

Table 3 and Figure 11 show the classification results, expressed as correct classification percentages (CCP). It can be seen that the subjects without mental disability reached high level of attention and meditation compared to the other subjects who presented cognitive disabilities. The subject 4 is the exception where he could get high level of meditation but not attention.

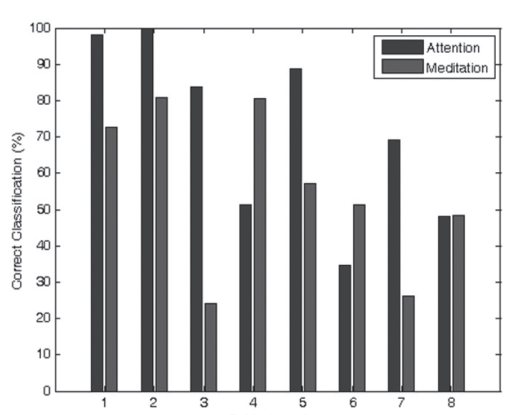

Figure 11. Correct Trial Classification (%).

DISCUSSION AND CONCLUSION

This paper described the design, implementation and test of an innovative and complex wireless system which was able to monitor, detect and respond according to mental signals, with an invaluable medical potential in bio-technology applied to health sciences and in particular targeting people that suffer from cognitive disabilities.

Despite the biosensors are more accessible due to its low cost, smaller size. The complexity of many new devices and solutions risk that many of potential users are unable to use them due to its disabilities. Therefore is very important and challenging to create services and system that communicate is a simple way with users. This is conceivable by getting experts from different areas to discuss AAL application design and user involvement when disabilities are present.

It was fruitfully analysed and evaluated the possibilities of use currently available bio-sensors like wireless EEG headsets, Skin conductance and heart rate together with the use of Tablet PCs in smart environments for detection of mental state with external stimulus like light and music. It was also analysed and assessed Arduino BT platform for controlling a light system. Some successful tests were done with the main stakeholders and the data was examined and plotted.

The prototype was established to measure the level of attention, meditation and a threshold for its response was set. This threshold was obtained from the analysis of data gathered from the tests with the experimental group. The executed tests showed that the system responds automatically to a mental state and communicates to the sound and light system wirelessly. The initial communication from the Tablet PC to Arduino platform was a bit problematic due to some issues in recognizing the MAC address of the device. These issues were successfully solved and the communication was established without inconvenience.

According to the data and results gathered from the interviews, it would be very difficult and maybe impossible to measure the brain waves, by using a Brainband, of persons that suffer from cognitive disabilities like autism. The experiment showed the opposite, which does not mean that it was a simple task, but with the help of the caretaker Jesper Foghmar, our goal could be accomplished. It would be also essential to apply more methodologies to approach better the participants in order to not affect the data gather due to their anxieties when meeting new people. One way could be done by establishing longer relation with participants and involving more caretakers.

The tests conducted with the prototype were very successfully, it was possible to understand the way that these tests have to be conducted. People with cognitive disabilities have different behavioural patterns, which makes it sometimes more difficult to conduct a test and interact with them. There is also a challenge in the analysis of data due to the short time extension of the executed tests. We think that conducting tests with a longer duration in time with the same type of end-users, it could be possible to gather more valuable and reliable data.

FUTURE WORK

Security and privacy are also a very important area when developing an application which involves user's data stored in a data base and using via wireless communication. The type of data that is involved for this service is very sensitive and should only be accessed just by the right persons. An analysis of where the data should be stored and who has right to accessing it should be done in upcoming work. Despite the fact that it was not included in this paper, possible security attacks to wireless networks like Bluetooth is not likely to happen, since this is a quite secured protocol, due to the use of frequency hopping for transmitting data in 79 channels. This makes it difficult to sniff in a communication system like the prototype presented in this paper.

It would also be important to test the impact of light and sound in end-user's mental state during a longer period of time.

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