Therapeutic Activities for Elderly People based on Tangible Interaction

Eva Cerezo[1,2], Clara Bonillo[1] and Sandra Baldassarri[1,2]
[1]*Departamento de Informática e Ingeniería de Sistemas. Universidad de Zaragoza, Spain*
[2]*Instituto de Investigación en Ingeniería (I3A), Universidad de Zaragoza, Spain*

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Abstract: The use of natural user interfaces in rehabilitation can contribute to increase the motivation of patients during the rehabilitation process. Among them, Tangible User Interfaces (TUI) which couple digital information to everyday physical objects, are considered to be intuitive and especially suitable for elderly people. The physical interaction with real objects can improve the quality of training for patients who need cognitive and/or motor rehabilitation. To explore the use of tangible interfaces with the elderly, a tangible tabletop designed by the AffectiveLab was settled in a nursing home. First of all, the general user experience of their clients when working with the tabletop was assessed. From this initial evaluation tips for the creation of tangible tabletop activities for elderly were obtained and applied to the design of new cognitive and physical stimulation activities for them. From this experience, guidelines for the design of tangible activities for this kind of users have been extracted and presented in the paper.

1 INTRODUCTION

In the last years, the amount of work aimed to investigate the potential of the information and communication technologies (ICT) for enhancing the wellbeing of elderly people, has considerable increased. The main focuses of these researches include combating physical and social isolation and loneliness, improving social interaction, digital skills and, specially, they are centred in the improvement of physical and mental health (Gamberini et al, 2008). New technologies, with their different ways for interacting, became an important therapeutic, non-pharmacologic tool, and not only an entertainment issue (Belleveille, 2008).

Although old people use to have some initial barriers in accepting digital technology due to their inexperience or accessibility difficulties, it has been demonstrated that the use of digital applications and games (Barbosa et al, 2017) which are meaningful in older users' lives (Cañas-Bajo et al, 2016) have carried very beneficial and positive impact from active aging, facilitating real change in older people's physical or cognitive abilities (Howe et al, 2017). Several studies verify an improvement in more than 75% of the cases (Zhang and Kaufman, 2016; Nguyen et al, 2017) although there are other authors that indicate that long-term results are limited, making it difficult to access the benefits for older people over time (Cujzek and Vranic, 2017).

Nowadays there are a lot of works that have introduced digital activities and games to achieve these objectives for older people (Schutter and Brown, 2016; Nguyen et al, 2017; Cota and Ishitani, 2015; Levine et al, 2016) mainly in three areas: for promoting socialization activities (Myhre et al, 2017), for physical exercises and rehabilitation and for cognitive improvement and rehabilitation (Wittland et al, 2015; Loos, 2017). In fact, nowadays therapists have at their disposal numerous tablet and smartphone applications aimed at helping people with physical and/or cognitive impairments. However, these devices are usually based on tactile interaction that requires the client to perform relatively precise tactile gestures for adequate finger detection, which can be difficult to achieve for people who suffer from motor or cognitive impairments. On the contrary, natural interaction-based applications may offer some extra benefits to therapy. The tangible interaction approach proposes that the interaction between the user and the application should be done using physical objects of daily use (Ishii and Ullmer, 1997). Among these

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tangible innovative systems, the use of tabletops in the therapy context has begun to spread during the last 10 years. A tabletop is a computer device whose physical appearance is very similar to a normal table. Its surface is virtually augmented using a projection of images and sounds coming from a computer application, and the interaction is carried out through movements of the fingers on the tabletop surface (multi-touch). In the case of tangible tabletops, the device is able to detect and identify the different objects placed on its surface, to track the different manipulations that users carry out with them and to show information related to those manipulations on the surface (tangible). This manner of interaction has several advantages, since the wide surface of the tabletop provides a large space to work the user's visual but also motor skills, the audio-visual stimulation motivates them and they can work with a bigger range of activities that cover one or more aspects of cognitive stimulation. Additionally, by keeping the objects on the physical side of the user, not only the emotional impact of the game is reinforced (Iwata et al, 2010), but also important benefits emerge when applied to young children (Marco et al, 2013a), children with special needs (Li et al, 2008), the elderly (Gamberini et al, 2006), and people with motor or cognitive disabilities (Leitner et al, 2007). Nevertheless, and in spite of their potential, tangible tabletops applications in therapy are rare.

The AffectiveLab of the University of Zaragoza has developed NIKVision (Marco el at, 2013b), a tangible tabletop device. NikVision is a vision-based tabletop initially designed for very young children and children with special needs. Thanks to an agreement with the Aragonese Institute of Social Services (IASS) we were able to settle on of our tabletops in a big public nursing home. In this paper we present the tangible activities we developed specially for the clients of the nursing home.

The paper is organized as follows. Section 2 is devoted to present the state of the art about tangible tabletops and rehabilitation. In section 3, the NikVision tabletop and the first experiences in the nursing home are presented. Section 4 presents the tangible activities developed and their evaluation with the nursing home clients. Section 5 presents the discussion and, finally, in section 6, the conclusions are exposed.

2 STATE OF THE ART

Following, a revision of tangible interaction experiences for old adults in rehabilitation, mainly focusing on tabletops, is presented.

Leitner et al. (2007) present a prototype of a tabletop specifically for cognitive and physical rehabilitation. The authors also propose several activities based on the manipulation of cubes with different patterns drawn on them. To complete the task, the user must align the cubes to form the same image as that shown on the tabletop surface.

Gamberini et al. (2006, 2009) have developed several memory game activities for keeping old people cognitive skills by using a tabletop. The users interact with the tabletop by manipulating special pencils. The tabletop allows playing up to four persons, who can be or not collocated around the same tabletop device, since different tabletops can be connected remotely. The *Memo-game* activity is similar to the popular game of finding pairs, in which the users gain points when making pairs and lose points when they fail to pair two images correctly. Some *Minigames* activities can be done for recovering the points when they lose. The aim of these games is to improve cognitive functions like memory, reasoning, selective attention, divided attention and classification.

Other applications have been developed for the cognitive training of adults and elderly people (Kwon et al, 2013): the E-CoRe system (Embodied Cognitive Rehabilitation System) is aimed to delay or prevent cognitive problems by training three specific cognitive processes: attention, memory and reasoning. For this purpose, they use tangible objects and a tabletop interface to train patients to perform activities of daily living (Jung et al, 2013). The application simulates making cookies by manipulating different objects, adjusting the number of cookies, selecting their shape and setting the oven temperature, and then, adding syrup and toppings to their cookies. The users have to follow certain instructions while remembering the steps that they have already done, so they are continuously working their attention and memory skills. In a later work, (Song et al, 2016) compared tangible tabletop-based training, with the E-CORE platform, with computer-based training, that involves singular mental tasks using keyboard and mouse, with RehaCom application. Although the sample is small, they found that embodied cognitive rehabilitation helps improve patients' cognitive functions and increases patients' motivation for rehabilitation.

Also, an European Research project called *Sociable* (Sociable, 2019) has been carried out a for cognitive training. It is focused on people with cognitive disorders and uses a tactile tabletop to run a great variety of activities organized in categories: memory, attention, reasoning, language and orientation. They have developed tactile tabletop versions of popular games like Finding pairs or Guess Who, together with several activities very similar to traditional puzzles.

Finally, there some other works that successfully use tangible interfaces to improve social skills. In this way, different tabletop games (Mahmud et al, 2010) for stimulating social interaction were designed, in the first place for improving interaction between children and older people and in the second to promote wellbeing. Also, there are some tangible products that have been used for improving social networks in elderly people. TEPOS (Tangible Entertainment Projection System) is an entertainment device that connects the real world with digital world for elderly people to engage with families and other people by projecting different games on any surface (TUVIE, 2019).

Regarding physical and motor rehabilitation through tabletops and tangible interaction, there are many works focused in limb rehabilitation after traumatic brain injury or stroke (Annett et al, 2009, Kwon et al, 2013, Mumford et al, 2008).

As conclusion, many works have already proven the advantages of using tabletops and tangible interaction in rehabilitation of elderly people. This is why we decided to install one of our tabletops in a nursing home as it is explained next.

3 NIKVision TABLETOP AND THE ROMAREDA NURSING HOME

3.1 NIKVision Tabletop Description

NIKVision (Marco et al, 2013b) is a tangible tabletop based on the physical manipulation of physical objects over the table surface. Any object can be used to interact with the tabletop on the condition that a printed marker (called fiducial) is attached to its base (see Figure 1). Theses markers are recognized by using reacTIVision visual recognition software (Kaltenbrunner and Bencina, 2007) to track the position and orientation of the pieces placed on the surface (see Figure 2c). An infrared light USB camera (see Figure 2b) captures video from underneath the table and streams it to the computer station which executes the visual recognition and activity software. Active image projection on the table is provided by rear projection (see Figure 2d) through a mirror inside the table (see Figure 2e) and the speakers (see Figure 2f) reproduce the audio of the activities.

Figure 1: Example of fiducial attached to a playing piece.

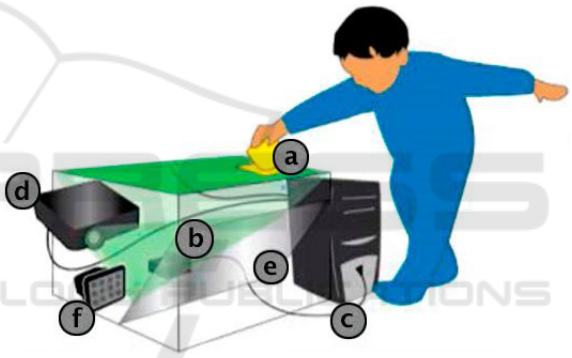

Figure 2: NIKVision Tabletop.

3.2 Case Study

A NIKVision tabletop was installed in the Romareda nursing home thanks to an agreement with the Aragonese Institute of Social Services (IASS). This nursing home is considered the reference home in the region.

Once the tabletop was installed, it was decided to carry out an initial evaluation to detect how elderly people react and their user experiences.

The Romareda therapy group was composed of thirty-seven people (23 women and 14 men) aged 63 to 99 years with different mental health problems. With the help of the occupational therapist (OT) the clients were divided in turn in two subgroups:

- **Cognitive Problems:** people belonging to this group suffered from attention and memory problems. They had also hearing and eyesight impairments, and got easily tired and

distracted. During their regular therapy sessions, they did activities like finding the differences or similarities between images and puzzles.

- **Dementia:** people belonging to this group need the constant help of the therapist in order to do their therapeutic activities. They presented problems of concentration, memory, autonomy and self-control.

The clients tested, individually, activities that had been previously created: memory, attention and reasoning activities (for more details see (Bonillo et al, 2019)). With this evaluation we wanted to have a first measure of the user experience while doing the activities on the tabletop. Several people took part in the evaluation session: the OT of the Romareda nursing home, who helped the clients while they tested the activities, and two experts, in charge of observing, taking notes and providing the clients with the pieces to be used. It was decided not to take photographs or film the tests as the OT explained that they would feel annoyed and it could make them act not naturally or not act at all.

3.3 Lessons Learned

The vast majority of the clients was satisfied with the activities with the tabletop and expressed their desire to use it again. Some very interesting conclusions were obtained:

- Almost all the clients needed a practical example of the activities to know how to complete them. For that reason, we concluded that it could be necessary to add an initial task just at the beginning of the activities that explained how to complete them.
- Many of the activities were too difficult for many of them: therefore, when designing activities several levels of difficulties have to be considered carefully and the OT has to be able to select one of them and/or switch from one to another during the session.
- Practically none of the clients paid attention to the feedback. The clients ignored the audio that sounded just at the beginning of the activities and that explained how the activity had to be done, since the clients were used to hear the instructions directly from their therapist and consequently they did not identify the audio that was sounding from the tabletop as such. Also, they did not understand either that the neutral, happy and sad faces that appeared on the activities were indicating the result of their actions on the tabletop. They just saw them just as mere decoration of the activity.
- The typology of the pieces did not pose any problem as they accepted both those flat and those three dimensional. But they had difficulties recognizing some objects. The therapist suggested that for future activities it could be better to use real images instead of pictures, since probably that way the clients would be able to recognize them more easily.
- Clients with wheelchair had difficulties to complete some activities. These clients had to resolve the activities laterally in order to be able to perform the activities on the tabletop. Besides, the clients who also had bad mobility in their upper limbs had difficulties when completing the activities that required to place the objects in the superior (or even centre) zones of the tabletop.
- The OT expressed the importance of promoting social interaction between their clients and suggested the design of a new multiplayer activity for the tabletop.

After the general positive feedback obtained from these first evaluations from clients and therapists, we decided to design new activities specially designed for them, following their feedback and recommendations. Due to the extreme difficulties that dementia patients encountered with even the easiest activities it was decided to focus on the cognitive problems group. The new activities are presented in the next section.

4 TANGIBLE TABLETOP ACTIVITIES FOR THE ELDERLY

Three new activities were designed. From these, one of them was especially devoted to work upper-half motor skills. It was the first of this kind designed for the NIKVision tabletop.

All the activities were developed by using KitVision, a toolkit designed to create tangible activities for the NikVision tabletops (Bonillo et al, 2019). The new activities have been designed with several different levels of difficulty so that the therapist can choose one of them depending on the client's abilities. All the activities begin with an audio explanation that indicates the objective of the task, together with a positive audio feedback of the answers of the user.

Next the three new activities are presented, explaining their aim and levels of difficulty, the physical and virtual objects they use and their therapeutic goals.

4.1 Clothes Activity

Aim of the Activity: This first activity is based on the daily task of getting dressed and has three different levels of difficulty:

- **Easy:** the background shows a body part (hand, feet, head…) together with the silhouette of two pieces of clothing. One of them corresponds to the body part while the other do not. The user has to select the correct one and place it on the right body part (see Figure 3).
- **Medium:** this time instead of a body part, the background shows the whole body of a person (man or woman). The user has to select the clothing that corresponds to the gender of the person: for example, heels or skirt to the woman, and shoes and pants to the man.
- **Difficult:** in this level, the users have first to complete a word related to the weather with the vowels missing: "Sun", "Rain", and "Snow". After that, the background shows a person together with four different pieces of clothing. In addition, through a window the weather that the users have just completed can be seen. Then, taking it into account they have to choose the most adequate clothes to wear: for example, if it is sunny they have to choose the sunglasses and the fan (see Figure 4).

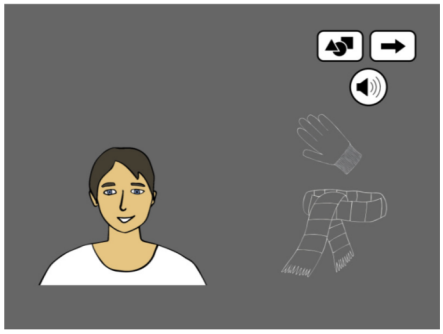

Figure 3: Clothes activity (easy level).

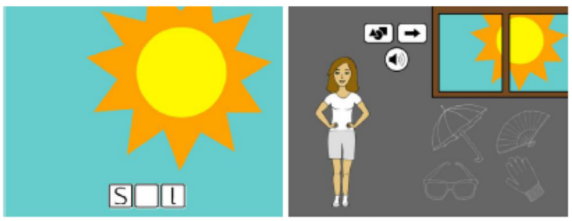

Figure 4: Clothes activity (difficult level).

Virtual and Physical Elements: The virtual elements consist of the different background that shows the body parts. Users interact with the tabletop by using different objects with realistic drawings of pieces of clothing and letters (see Figure 5).

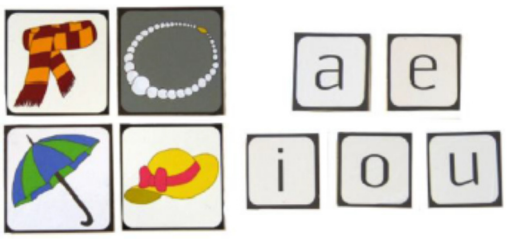

Figure 5: Objects of the Clothes activity.

Therapeutic Goals: this activity allows the consolidation of the semantic memory in the field of the clothing, together with the weather.

Also, it allows working the relation between analogous elements thanks to the association of the clothing with its corresponding body part, and the relation between different elements when you have to choose clothes depending on the genre and on the weather. In the most difficult level, language is subtly worked thanks to the words that have to be completed to advance in the activity. Fine motor skills are addressed when users have to pick up the two-dimensional objects to place them on the tabletop. Finally, the audio feedback (changing between man and woman depending on the task) enhances the short-term memory and complements the information showed on the tabletop.

4.2 Shapes Activity

Aim of the Activity: In this activity users have to select the shapes indicated by the activity and situate them on the box displayed on the tabletop. There are two different levels of difficulty (easy and hard) and a multi-player level that combines tasks that appear in the easy and medium levels.

- **Easy:** this level is focused on the work with a single type of shape (circles or squares) but with different sizes and colours, increasing the number of pieces involved with each task.
- **Hard:** in this level the users work with the two types of shapes. In this level, the number of correct answers increases.
- **Multi-player:** in this case, all the available toys are divided in two so that each player has

half of them. Also, the division is made in a way that the solution contains pieces belonging to both users, so that they have to collaborate to complete the task (see Figure 6).

The use of feedback and the navigation menu is the same as in the previous activity.

Virtual and Physical Elements: the virtual elements of this activity consist of the background showing the box and the different geometrical figures involved in the task. Users interact with the tabletop by using geometrical shapes (see Figure 7).

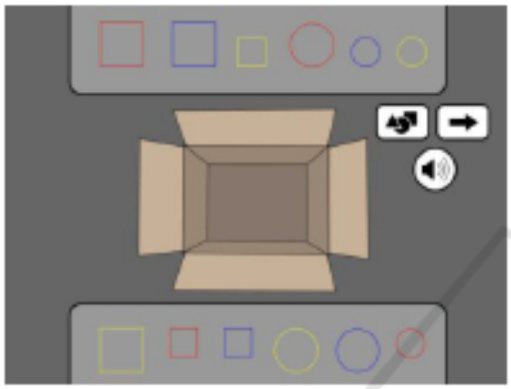

Figure 6: Shapes activity (Multi-player).

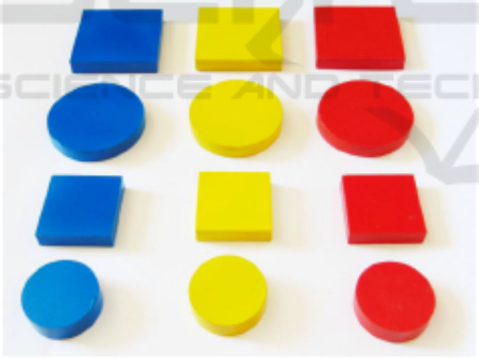

Figure 7: Objects of the Shapes activity.

Therapeutic Goals: this activity allows working the association between physical elements with the concepts they represent, together with the inductive reasoning that allows carrying out the process of thinking from the specific concepts to the general concepts. In the multiplayer level, the activity fosters the communication between the people that are playing and cooperation, since they need to work together to complete the task. The use of two-dimensional pieces enhances, again, fine motor skills. Finally, short-term memory is reinforced thanks to feedback completing once again the visual information displayed on the tabletop.

4.3 Roads Activity

Aim of the Activity: the last activity is focused on upper-half motor skills. Users have to move the object on the tabletop surface by following a virtual road, and also by avoiding physical obstacles in the most difficult levels. Again, this activity has three different levels of difficulty:

- **Easy:** the different tasks just have a single road and there are not any obstacles. The roads are rather straight, without many bends.
- **Medium:** obstacles begin to appear and each task has two different roads to choose. An audio plays saying which road (red, green or blue) the user has to follow, and the user has to select it with the corresponding object.
- **Hard:** in the most difficult level the two roads interject so that the user has to pay attention and continue for the correct road. Also, in the last tasks both roads are of the same grey colour, to increase the difficulty even more. Obstacles are placed in all the tasks (see Figure 8).

In this case, an audio was added as feedback to indicate the user when he/she is deviating from the path.

Figure 8: Roads activity (hard level).

Virtual and Physical Elements: the virtual elements are the backgrounds showing the different paths. The objects with which the users interact are different handles designed to work different kinds of "grabbing" actions (see Figure 9). The obstacles used in the most difficult levels are also physical (see Figure 10).

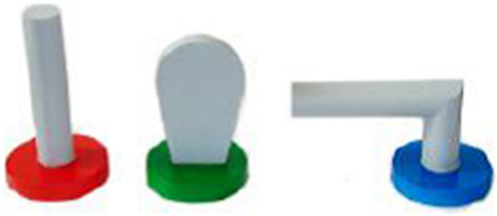

Figure 9: Objects of the Roads activity fostering different "grabbing" actions.

Figure 10: Obstacles used in the Roads activity.

Therapeutic Goals: the activity allows the development and maintenance of procedural memory in the use of tridimensional objects with different handles, representative of different daily situations. Fine motor skills are addressed, especially the movement of the upper limbs. Also, spatial orientation is worked, together with divided and sustained attention since in the most difficult levels the user has to focus his/her attention on one of the two different paths, and to concentrate to follow it correctly. In general, hand-eye coordination is worked, fostering the skill that enables the eyes to guide the hands in accurate movement.

4.4 Evaluating the New Activities

The evaluation session took place in the room of the nursing home where a NIKVision tabletop was installed. The clients were called one by one in order to test the tabletop activities.

Before beginning with the activities a small questionnaire was made (orally) to the user, with the name, sex, age, mobility of the upper limbs and trunk, if he/she used wheelchair and the type of contact with the technology. One of the researchers was in charge of explaining very briefly the activity to be performed to the clients and help them. Questions about every activity were made just after having tested the activity.

Initially, it was about getting those clients who had already worked with the NIKVision table, but after the indisposition of certain patients, some other people who met the characteristics of target users (adults with cognitive problems but not dementia) were recruited, about half of them using wheelchairs. The users tested individually the cloths and roads activities; then they played in couples the shapes activity.

In the *Clothes* activity the clients were able to recognize the pieces of clothing and divide them according to genre. They took their time placing the objects on their corresponding place (pants/skirt on the man/woman's legs, or shoes/heels on the man/woman's feet). They understood the audio instructions but they usually needed to hear them more than once. They had more difficulties with the Hard level of difficulty: they have to complete the words related to the weather, since they focus on what the audio is saying to discover the word that they have to complete, and sometimes the audio does not say it directly (for example, the audio says "it's raining" but the word they have to complete is simply "rain").

In the *Shapes* activity, the clients had more difficulty with the Medium level of difficulty where they had to place on their own, performing better on the collaborative level since the number of pieces they had to manipulate was lower. A good interaction between players was observed, and sometimes they even helped each other to be able to complete the exercise. One thing that would be necessary to improve for the next version of this activity is the size of the virtual box: it should be bigger so that clients did not have to waste too much time in reorganizing the pieces so that all of them fitted well inside.

Finally, in the *Roads* activity the clients reacted well with the different way of grabbing. They were able to follow the roads, presenting the expected difficulties in the last level of difficulty when the roads overlapped. They also managed to overcome the physical obstacles while playing. However, the audio feedback was a little slow to sound when they stepped out the road, and it was decided to widen the roads for the next version of the activity.

In general, the evaluation was positive and, in spite of the few mistakes detected in the design of the activities, it was observed their adequacy to the target group they addressed.

5 DISCUSSION

The developed activities were evaluated with elders with cognitive problems because of their age. These people are amongst the most vulnerable groups in most countries and they could benefit from new

computerized tools and interactive devices. While guidelines for design for these users have been suggested, most of them discuss rather low level details of accessibility, such as alt texts for images, or navigational design. The lack of research on the impact in the collective of the latest interactive paradigms, such as augmented reality, multimodal or tangible interfaces, is evident.

From our experiences with the elderly we obtained some interesting clues:

- Initial images containing clues or instructions have to be shown with enough time in order to be assimilated by the patients.
- The use of real images instead of drawings could be more suitable with elder users.
- For the patients with wheelchair, the interactive areas of the activities must be closer to the border of the tabletop so that they can reach them.
- Finally, regarding the feedback, there are certain users that do not pay much attention to audio feedback, since they are used to listening to the instructions from their therapist. In addition, some of them do not recognize the visual feedback as such, mistaking it as a decoration of the activity. Consequently, with this kind of patients it is necessary to rethink the way of giving feedback in a way that they could understand it. However, after analysing the behaviour and response of the users that paid attention to the feedback, we have deduced the following considerations to take into account when designing the feedback:
  - Wrong feedback (based on either animations or just sounds) should be used with care. Most patients are motivated by positive feedback, but some of the can easily be frustrated by negative feedback.
  - Visual feedback has to be placed close to the corresponding active area where the user is focusing his/her attention so that it is not missed.

We hope these reflections will be useful to other researchers and designers of interactive applications oriented to adults with cognitive impairments.

6 CONCLUSIONS

In this paper we have presented the experience of using the tangible tabletop NikVision in the cognitive stimulation of elderly people. Thanks to an agreement with the Aragonese Institute of Social Services (IASS) we were able to settle on of our tabletops in a big public nursing home. Thanks to that, we were able to carry out some initial evaluations to see the reactions of the older people to the tabletops and tangible interaction. The residents were divided into two main groups: the group with cognitive impairments and the dementia group. From the results of that initial experience, we were able to extract useful guidelines in order to tackle the design of tangible activities for the residents. It was decided to focus in the cognitive impairments group as it was stated to be the group that could benefit more the therapeutic potential of the tabletop. Three new activities were developed applying a user-center design approach with permanent contact with final users and their therapists. From the experience, we could extract guidelines for the design and evaluation of tangible activities for this kind of users that could be useful for other researchers.

In the near future we will focus our efforts in developing new activities and doing a long-term evaluation of the effect of the activities. Also, the acceptance by elderly people of this kind of technology, these activities over tabletops and the tangible interaction, will be analysed.

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