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Adaptive manuals as assistive technology to support and train people with acquired brain injury in their daily life activities

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Abstract Assistive Technologies and Ubiquitous Computing can be related since both try to help people in their lives. This common objective motivated us to develop and evaluate a system that puts ubiquitous computing technologies into the rehabilitation process of people with acquired brain injury. Thus, in this paper we present and evaluate a system that shows adaptive manuals for daily life activities for people with acquired brain injury. This first evaluation allowed us to validate our approach and also to extract valuable information about these systems as well as environmental factors that may affect the patients.

Keywords Acquired Brain Injury · mobile devices · assistive technology, QR-Codes

1 Introduction

Nowadays the assistance for care–dependent people is gaining importance as a research field since it could improve the quality of their lives and their relatives. This dependence may be caused by several circumstances, such as gross motor, or sensory or cognitive impairments. As a consequence of that impairments the person may present troubles to perform daily life activities, such as personal care, hygiene, feeding, etc.

According to the National Statistics Institute of Spain, over the 18% of the Spanish adult population suffers limitations to perform daily tasks.

In this sense, Ubiquitous Computing may offer new opportunities for researchers. The work developed in this area can be focused in many aspects: information technologies, communications, house living or healthcare assistance. We think house living and healthcare assistance are very related in some cases. Therefore, some of the work developed in the Ambient Intelligence Laboratory at the Universidad Autónoma de Madrid is focused on promoting the independent life of people with cognitive disabilities (Down Syndrome and Alzheimer's disease) [11][21][26]. Meanwhile, the Centro de Referencia Estatal de Atención al Daño Cerebral, CEADAC (Spanish Reference Centre for Brain Injury Care) is a public reference centre devoted to rehabilitating people with acquired brain injury. Therefore, they offer services for patients and relatives to promote their autonomy

This research area, where the technology is applied to help people with special needs is also known as "Assistive Technology (AT)". As it is defined in [1], "Assistive Technology is any device, equipment, instrument, technology and software produced to prevent, compensate, monitor, relieve or neutralize impairments of body structures and body functions, restrictions in activities and problems in social participation".

In this paper we will focus on the rehabilitation process of one patient with acquired brain injury. Many experts of different areas participate in this rehabilitation process: occupational therapists, physiotherapist, neuropsychologists, etc. Part of the job of these experts consists of helping patients to acquire a greater level of autonomy in their daily life activities and adapting and modifying the home environment. Since the aim of Am-

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bient Intelligence, as a part of Ubiquitous Computing, is helping the inhabitants of an environment, it seems that these techniques may be useful in the rehabilitation process.

The system proposed in this article tries to help people with acquired brain injury in their daily life activities. Since these patients usually present problems in performing their everyday tasks [12], we propose a solution to guide them during the activity by providing step by step instructions. This way, a therapist or caregiver can define a set of instructions or tasks to should be followed to complete an activity, this is, a guiding manual. After that, she can print the corresponding QR Code (that contains the information related to the activity) so the user can scan it by pointing at it with her mobile phone. Finally, the manual (adapted to user necessities) is presented in the device. This adaptation is provided in two ways: firstly, the amount of guidance can be reduced for a particular patient so she receive a shortened manual; secondly, setting different alarm times for each patient: a therapist or caregiver can configure a timer which alerts the patient by playing a sound or reading the task aloud so she is warned in case of getting blocked. In addition, the therapist or caregiver will receive a full log of the execution to analyse the progress of the patient.

According to Cole [7], AT design should be patient–centered. In this way, we consider that either relatives and the clinical team who rehabilitates the patient must be included in the design process since they may contribute valuable information about the necessities and patients' limitations.

Another consideration is the high–rate of abandonment that Carmien [5] and Martin et al.[22] reported. They detected that the less the user (patient or rehabilitation team in this study) is implicated in the design process, the higher probability of technology abandonment we get. This abandonment may also come from the complexity of the system or the adaptation shortage.

In order to promote patient's independence and make the information more accessible, these instructions are shown in mobile devices as well as are adapted to their needs. As we will see in latter sections, either the user interface and the sequence were discussed with the rehabilitation team, so the design was centred on the patient.

2 Related Work

In this article we are going to focus on technologies for people with special needs. In this way, we find two great areas: technologies for sensoring and retrieving information from the patient and technologies that assist her in her daily life.

The first one is well–known as "tele–health", an area in continuous development whose main objective is measuring the state of the patient (vital signs, collapses, mood, etc.) to predict dangerous situations and make the caregiver task easier, since she can "observe" the patient without being together. In the literature we find many works related to this area, in [16], [14], [15], [17], [10].

The second area, which is defined as "Assistive Technology (AT)", tries to promote the independence of the indiviual by assisting her. This assistance may be given in many ways and in many situations or needs. In this article we are paying all of our attention in daily life activities for people with cognitive disabilities. In this sense, we will refer to "cognitive prosthetics". This term was coined by Kirsch et al. [18], and defined as "a compensatory strategy which alters the patient's environment for performing specific functional activities". A few years later, Cole [6] expanded this term and added a set of attributes: uses computer technology, is designed specifically for rehabilitation purposes, directly assists the individual in performing some of her everyday activities and is highly customizable to the needs of the individual.

In Tsui and Yanco [29], we find there is an up–to–date revision of devices for memory aids for task sequencing. Besides, it offers end-user evaluations for some of the projects studied. They talk about four kind of aids: "no-tech ATC", such as pictureSET[1]; ATC that support linear sequences, such as iPACS[2], iPrompt[3] (both for Apple's iPhone/iPod/iPad) and The Jogger[4]; ATC devices that support branches, PEAT (Planning and Execution Assistant and Trainer) [20] and Visual Assistant [9]; and finally "ATC devices with artificial Intelligence" are introduced (GUIDE [27] and COACH [25]). Related to this area, we find another project [13] that uses activity–aware computing to offer assistance to elders in their daily life activities.

This survey can be extended, as Boger and Mihailidis did in [4]. In this article they present a review of the most challenging works in progress. Firstly, they talk about autonomous detection of changes in health, that is what we called "tele–health" previously. After

[1] Special Education Technology: PictureSET. Online at http://http://www.setbc.org/pictureset/

[2] AdastraSoft: iPACS. Online at http://www.adastrasoft.com/

[3] Handhold Adaptive: iPrompts. Online at http://www.handholdadaptive.com/iprompts.html

[4] Independent Concepts Inc.: The Jogger. Online at http://www.thejogger.com

that, some projects related to wheelchairs with artificial intelligence are presented. Finally, a review of projects for supporting activities of daily living is discussed. In this section they talk about four works: Archipel [3], COACH [25], ePad [24] and Brain–Computer Interfaces with Rapid Automated Interfaces for Non – Experts (BRAIN) [28].

The work we present in this article can be embraced under Tsui and Yanco classification on the topic "Personal Electronics as ATC Devices". As we will see in latter sections, our proposal presents adaptive manuals to perform everyday life activities in mobile phones. They facilitate the rehabilitation process by allowing to adapt for each user the amount of guidance needed to perform the task, as well as providing a detailed execution log to the caregiver.

This system is targeted towards people with Acquired Brain Injury (ABI). This disease is the result of damage in the structure of the brain that can provoke a wide variety of problems. This damage can be caused by a stroke traumatic brain injury, tumors, etc. Middleton defined in [23] a set of after-effects: three groups that affect directly to the patient, and another one for the possible problems that affect to their relatives. The ones that affect to the patient are:

- Physical effects: gross motor difficulties, epilepsy, tremor, sensory loss, etc.
- Cognitive effects: speed of processing, attention and concentration, language and communication, visual, perceptual and spatial skills, memory and learning and executive skills.
- Emotional and behavioural effects: lack of inhibitions, impulsiveness, irritability, fatigue and inertia, anxiety, fear, grief, post-traumatic stress disorder, etc.

In this system we have concentrated our efforts to mitigate cognitive effects but physical effects were taken into consideration. One of the requisites the target population had to accomplish was to be able to move themselves without external aid and handle appliances and small items, so they did not have to suffer severe motor difficulties. On the other hand, emotional and behavioural effects were not in our centre of attention but we consider that some of them would be softened according to the progression of the patient. Finally, focusing on cognitive effects, we pursue to contribute to the progression of the patient in memory, initiative, learning and executive functions.

The rehabilitation process is critical. It should start as soon as possible (this is, after being medically stable) and, as the IMSERSO[5], the rehabilitation process should work on seven areas: alert level, motor control, information processing, communication, cognitive level, emotions and personality and everyday life activities. This last area, daily life activities, is highly related to motor conditions and cognitive disabilities, and it is considered an important area to work during the rehabilitation process because it increases the independence of the patient [12]. We think this is the area where adaptive manuals can provide an added-value in the rehabilitation process.

3 Adaptive manuals for daily life activities

As we said before, patients who suffer acquired brain injury may present memory and executive functions deficits. In concrete, some patients could have problems to engage in how to perform daily life activities, such as doing the laundry or ironing a shirt. This difficulty has motivated us to think about a possible system that may help them in their daily routines.

In this article we propose the system "aQRdate" (read like *acuérdate* –remember– in Spanish). We plan to generate a personalized set of instructions to perform an activity and show it in mobile phones. In order to avoid the user selecting the activity from a list or introducing the name, we decided to employ QR Codes. These codes store all the information needed to identify an activity. Besides, they can be printed, making the cost lower than other approaches such as NFC/RFID tags.

NFC/RFID tags present important advantages over QR Codes. First, they are invisible, so they should be used when aesthetic criterions are critical. Second, they can be reprogrammed once they are deployed. In the case of QR Codes it is necessary to replace the whole marker. Third, the read process in NFC/RFID tags is quicker than in the QR Code version.

However, even without the possibility of rewriting them, from our point of view, the main advantage of QR Codes over NFC/RFID is their greater flexibility regarding to end-user prototyping. Using QR Codes, end-users can create their own QR Codes without requiring any specific hardware (just a printer and paper). On the contrary, new NFC/RFID tags i) have to be acquired separately, ii) it is needed a writer device to configure them, and iii) are more expensive than the QR Codes version. Additionally, QR Codes can be virtually generated into any screen upon demand; mean-

[5] Instituto de Mayores y Servicios Sociales –Elder People and Social Services Institute–, under the authority of the Ministry of Health, Social Politics and Equality. Spain

while NFC/RFID tags are always tied to the physical world.

This way, the user only has to point at the tag with her device and when a QR Code is detected, the system automatically captures it and decodes it. The information stored in these QR Codes is the name of the activity. From this name, and based on the characteristics of the device and the necessities of the user, the system displays a set of instructions that can help the user to accomplish the activity. These instructions can be presented in different modalities: graphical, text and oral.

3.1 Target population

Our goal is to help people with acquired brain injury in their rehabilitation process, so we have to consider the next ideas:

- These patients may present a wide variety of injuries: motor control, diminished memory, communication restrictions (reading, writing, and even, speaking), etc. We should have all of them under consideration while designing tools for their assistance.
- We will focus in daily life activities as they are considered an important part of the rehabilitation process. These activities are usually linear (there are no choices) but different users may require different instructions.
- Occupational therapists may relay important information about interaction restrictions and needs.

Selecting an appropriate patient was a critical task to carry out our study. To do that in a standard way, the rehabilitation team proposed a set of epidemiological and socio-cultural criteria that the patient should satisfy:

- He had to present troubles to perform any daily life activity.
- He had to be able to understand simple orders.
- Learning and handling capability.
- Lack of initiative.
- Alteration of executive functions (planning, sequence, etc.).

According to that criteria, the rehabilitation team selected a patient (man, 39 years) that suffered a cranioencephalic trauma after felling off a horse. Among his lesions, we found:

- Severe deficit of executive operation with implication in behavioural regulation (planning and executing).
- Moderate anterograde amnesia.
- Bradypsychia (Slowness of mental information processing).

The deficit of executive operation involves that the patient presents problems in initiative and sequencing tasks. We considered that aQRdate might provide a valuable help in the completion of the proposed every day life task. The anterograde amnesia means that the patient can not create and remember new long-term memories. This involves that the knowledge he acquired might not be remembered after a period of time, so it would be recommended to check it. The slowness of mental reactions had to be kept in mind since he might present troubles to process complex orders.

3.2 Description of the manuals

The first task a therapist must do before including the aQRdate program in the rehabilitation process of a patient is to identify and describe all the steps that composes the activity in terms of activities and tasks. Activities represent a set of instructions (tasks) that have to be followed to complete a certain pursuit

Since different users may require different set of instructions for the same activity, an adaptation mechanism was provided. We can define the sequence for a generic user but we can also create new next/previous relations between tasks for different users.

3.3 User Interface

According to Larsson et al. [19], the use of everyday technologies in the rehabilitation process of people with acquired brain injury provides significant benefits in the performance of everyday tasks. In order to test this, and following Barkhuus and Polichar [2] lines, we decided to employ mobile phones as user interface devices.

On the other hand, if we reintroduce the considerations that our system had to satisfy, we can extract some system requisites:

- Users have to be able to access the information anywhere and at any time. We consider that, if a user is performing an activity at the kitchen, she should not have to move to another room (where the computer is) to know the next step.
- Different users may require a different sets of instructions to perform the same task, so the system must be flexible enough to admit this.
- The interface should be adapted to the user, with her needs, and the device. This adaptation should also include modality (text, images, voice, etc.)

– Caregivers or therapists should be able to get data back from the execution.

As Cole posed in [7] and [8], clinical teams must work together with technicians in the designing process so it must be patient–centred. In this work, we considered as "the user" the clinical team, since they can contribute valuable information about the needs of the patients. Therefore, all the prototypes implemented were presented and discussed with the clinical team.

Once the design lines were stated, an Android application was developed to show the manuals. When the user starts it, a screen is presented where the content is the image captured from the camera in real time (See Figure 1 (a)). When the system detects a QR Code, it automatically captures and decodes it. All this process is provided by the "ZXing Library[6]" and "Barcode Scanner application[7]". After that, each step is shown following the guidelines proposed by the rehabilitation team: minimal information, both text, graphical and oral modalities and colours and symbol rather than text on the buttons.

We designed the interface that is shown in Figure 1 (b-d). The text at the top corresponds to the title of the task and is read aloud when it is loaded (if it is set in the configuration) or if the user touches the screen. Then, we have an image that represents the action. This is useful in some cases because it could help the user to identify the object she needs. Bellow the image, we have a small text that represents the current task number and the total number of tasks (or steps) required to complete the activity. Finally, there are two buttons to move to the next or the previous task.

The interface can be adapted to user preferences or needs. To do that, a configuration tool has been created. Thus, the therapist or caregiver can select the best characteristics for the patient.

4 Evaluation

Developing ATs presents a wide variety of opportunities and approaches, but only a few of them may satisfy user or task necessities. Therefore, we considered to test our system by means of including it in the rehabilitation process of the selected patient. This way we could extract information about his progress and, thus, validate our system.

After selecting a suitable patient that achieved the set of requirements presented previously, the activity had to be designed. Based on previous experiences, instead of creating a new activity, the clinical team elaborated a sequence that was already considered as an objective during the rehabilitation process. This activity consisted of preparing a breakfast: coffee with milk, orange juice and toasts with butter and jam. It integrates several cognitive and manipulative abilities such as memory, planning, sequencing and bi-manual coordination.

Therefore, the rehabilitation team design the activity, by means of the different tasks that composed it. Finally, a set of 44 steps that formed 6 subactivities were produced: prepare coffee, prepare orange juice, prepare toasts, heat milk, add coffee and prepare the table.

4.1 Methodology

Once the rehabilitation team completed the manual, the patient carried out a total of sixteen sessions:

– An initial test session without any technological aid, to acquire a reference that allowed us to evaluate the progression.
– Fourteen sessions using aQRdate. The first three were performed at CEADAC and the rest at patient's home.
– A final test without aQRdate to check that he was capable to do the activity by his own.

The first session consisted of preparing a breakfast without any technological aid. During this session, we measured the number of tasks he did, the number of times the therapist had to guide him, and the total time it took him. All this information provided a starting point to evaluate the progress of the patient.

The next step was to include aQRdate in his rehabilitation process. A mobile phone equipped with aQRdate application and the corresponding QR Codes were given to the patient. He tried the application for three times in his therapy at CEADAC. This way, the patient got accustomed to the phone, the interface and the instructions. In addition, we could validate the interface and check if the guidelines we followed on its design were correct and they adapted to user necessities. After these three sessions at CEADAC, he used it at home in his everyday live for eleven times more. In this period we realized that he was improving his times, so therapists adapted the sequence to reduce the guidance.

Finally, a couple of weeks after the last session, we decided to ask the patient to prepare the breakfast again without any technological help. This way, we were able to test if he could do it autonomously.

[6] Online at http://code.google.com/p/zxing/
[7] Available at the Android Market for free.

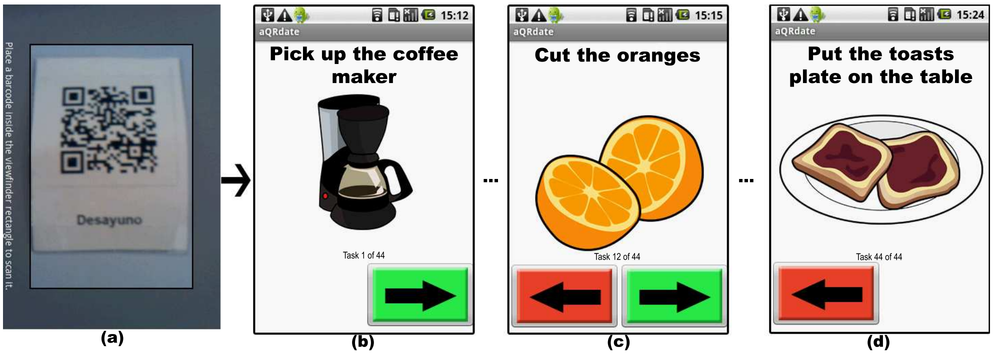

Fig. 1 Sequence interface. (a) Capturing the QR Code. (b) First task. (c) Intermediate Task. (d) Last Task.

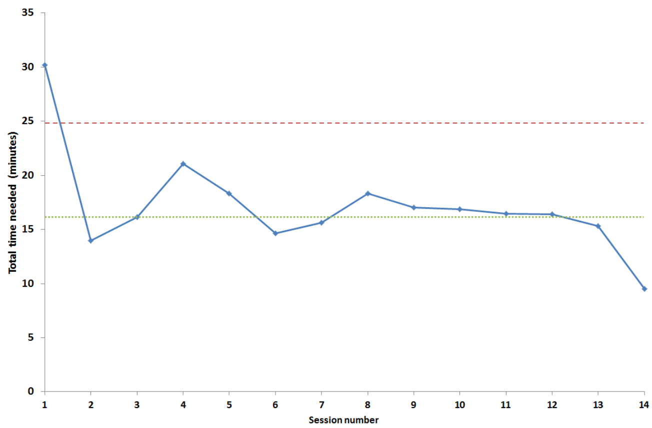

Fig. 2 Total time employed on each session with aQRdate (colid line) in comparision to the first time he permormed the activity (broken line) and the final test (dotted line)

4.2 General results

The whole progression (measured times) can be seen in Figure 2. In the graph we have represented the total time that the user employed in each session (solid line), the time needed in the first test without aQRdate (broken line) and the time he spent in the last test without any aid (dotted line). As can be seen, it took around 25 minutes to prepare the breakfast this first time.

The results obtained the first time he used aQRdate were disappointing, since he needed more time to perform the activity compared to the first test. Otherwise, sessions 2 and 3 were very encouraging. He improved his times more than a 40 percent compared to the first time he used the application. In our opinion, this improvement comes in part from the fact that he was more familiar with the application but, as it was reported by the therapists, he actually did the activity quicker and in a confident way.

After the three sessions at CEADAC, the user was given the phone to perform the activity at his home. As it is reported in the graph, the time needed raises in fourth session. At this point, we have to take into consideration that these patients are very sensitive to changes, so any alteration in their environment or habits may affect on their capabilities. In addition, patients are accustomed to use CEADAC facilities (the kitchen in this case), since they work there in their rehabilitation process. In contrast, it is not very frequent that they do the domestic chores autonomously at home. All these factors involved that he learnt slowly at home but it is important to emphasize that he continued improving his times. After a oscillating period his times settled around 17 minutes in sessions 9 to 11, so the clinical team decided to adapt the sequence to reduce the amount of guidance and it resulted in a reduction of the time needed to do the activity (sessions 12 to 14).

Considering the results extracted from the logs provided by the system, we can conclude that the improvement was both in time and also related to independence. Regarding times results, the improvement was around the 30 percent. Moreover, he was guided less times and he was not told what to do next. In contrast, he was only guided about unplugging electrical appliances. Therefore, therapists consider that he could perform the activity by his own, without any external aid, making him more independent.

In addition to the graph, we can include the information provided by his relatives. They considered the system a useful tool in the early steps of the rehabilitation, since it promotes the independence of the patient. On the other hand, they notified that, as the patient progressed, the application lost its usefulness, since he was able perform tasks with no aid. We consider this is a good conclusion, since our objective is accomplished: make the patient independent enough to perform daily life activities autonomously.

This way, we are in position to say that aQRdate assisted and contributed in the learning process of the independent performance of the proposed activity. According to his clinical profile, he had troubles in planning and executing tasks, which we consider is covered by our system, since all the sequence is shown in a multimodal way. The multimodality provides a good way to present the steps, since some patient may present communication problems or, as in the case of this study, slowness in information processing. In this occasion images an oral instructions were critical. Without them, the patient may have needed a long time to read each step and perform it.

Besides, aQRdate provides mechanisms to help the patient in the case he gets blocked and does not know how to continue. He can consult the device anywhere and check the next step instead of asking a caregiver or therapist. Or even, he can get advised automatically, since aQRdate provides a mechanism to program alerts.

Another conclusion we can extract from the logs is that these programmed alerts were not as necessary as we thought, since he was only warned a few times by the mobile. At this point we have to study in depth alerts and therapists interventions. In the first session, without aQRdate, the therapist had to take part four times: two of them were critical while the other two not. We considered critical interventions to the ones that were essential since, without them, the patient would not have been able to continue doing the activity (in case of getting blocked or asking for the next step). The not critical ones were advices given by the therapists to remember him to unplug electrical appliances, that was only considered as a good habit.

During the sessions with aQRdate, interventions were measured as the number of times the alarm sounded. In general the alarm did not sound any time, so we are in position to consider that displaying the task was enough to make him finish the activity. In the final test the therapist took part two times, again to remember him to unplug electrical appliances.

Finally, thanks to the reports provided by patient's relatives and therapists, we are in position to state that he was independent enough to do the activity by his own, without any aid, what suggests that our proposal worked.

4.3 Environmental factor

In previous section we exposed that changing the environment may affect user results, but we did not specify how much. To study the influence of the environment we compared the improvement in time he presented in his sessions at CEADAC to the ones at his home. This information is represented in the graph in Figure 3.

The solid line represents the improvement (percentage) in time after a number of sessions at patient's house. The broken line represent the improvement (percentage) in time after two sessions at CEADAC. As can

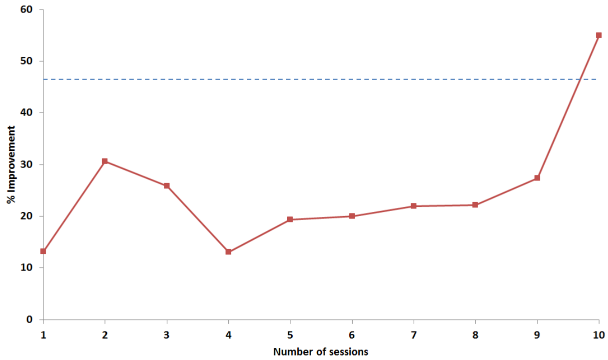

Fig. 3 Improvement in time (percentage) for each session at patient's home

be observed, the user needed 10 sessions to obtain a better improvement at home than the one obtained at CEADAC after two sessions. In spite of doing the rehabilitation at his own home, his results were not as good as the ones at CEADAC. This may come determined because he probably was more familiar with the CEADAC environment than his own home.

We can conclude that it affects in the performance in the way that the patient required more time to do the activity, motivated by the fact that he was not so familiar with the second environment. Therefore, doing a previous work in the environment with the patient to make it more familiar to him is essential to make the most of the proposed system.

In general terms, one conclusion we can extract is, when developing and evaluating AT systems, the familiarity that the patient has with the environment would affect performance results. But, once the patient get accustomed to new environment, his progression can be as good as it could be in other known environments.

4.4 Sequence adaptation

Once accustomed to the environment, the user presented a continuous improvement in his times session after session. Although he seemed to be doing his best, the rehabilitation team considered that he could do it better, so they adapted the sequence to reduce the amount of guidance (sessions 12 to 14). This adaptation was motivated by the fact that the patient only needed the first step of a subactivity (pick up the coffee maker, in example) to perform the whole set of tasks. As the graph in Figure 2 reports, patient's times improved after this adaptation so the rehabilitation team's proposal was validated.

In this sense, we can go further and consider the graph in Figure 4, so we can refine this argument. Thus, preparing coffee, making an orange juice, preparing two

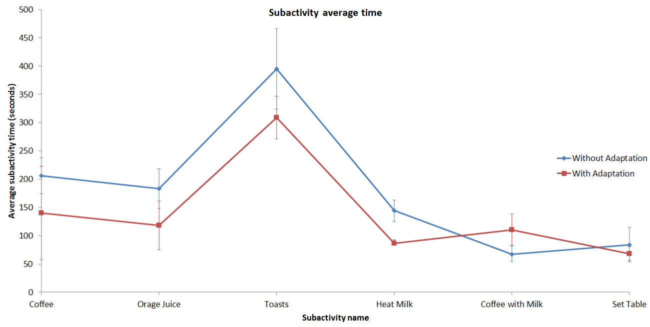

Fig. 4 Comparision between the improvement in time for each subactivity before and after sequence adaptation

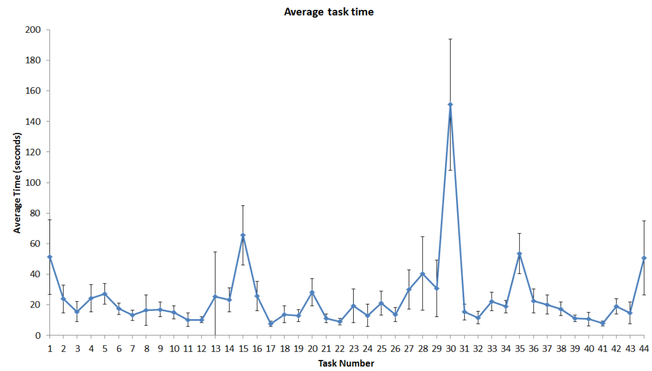

Fig. 5 Average time needed to perform each task

toasts and heating milk present an improvement around 30 percent, while adding coffee and setting the table do not seem to experience any reduction in time. This can be caused because both are smaller and simpler tasks so they actually took the best time possible for the patient.

Finally, we can extract the conclusion that, once the user seems to be doing his best, reducing the amount of guidance may provide improvements in his times, but we have to keep in mind that the improvements would be more significant for larger and more complex activities.

4.5 Tasks Analysis

As data collected reported, each task did not take the same time. Some of them were performed quicker than others. Figure 5 represents the average task time among the non-adapted sessions (at CEADAC and home). We can see five local maximums that correspond to tasks 1 (pick up the coffee maker), 15 (squeeze two oranges), 30 (spread butter and jam on the toasts), 35 (select heating time) and 44 (put the toasts on the table). Moreover, all these tasks that took longer were not equal: some of them required more cognitive load, others demanded bi-manual coordination and, some of them, just needed more time because of their nature (squeezing the oranges, i.e.).

For a first analysis, we decided to focus on these time demanding tasks to see if they all improved in the same way. Some of them (tasks 1, 35 and 44) decreased the time needed for the user for their completion, which means that the patient improved along the different sessions. We can say he got to the point of learning how to do the tasks autonomously and the system provided of a good help to reach this goal. In contrast, tasks 15 and 30 did not get any relevant improvements in their performance. He was just fluctuating his times but the final performance was around the initial one. We consider that these are just time demanding tasks that are not difficult for the patient. In this way, the employment of the system does not provide a reasonable improvement in their performance. Of course, the nature of these tasks may depend on each specific patient or, in a more general way, in the previous characteristics of his pathology. To identify in advance these tasks can improve the design of the system, dedicating fewer resources to those tasks where the user can manage on his own without the necessity of any technological help. Also, understanding what could be the most conflictive tasks, and giving more relevance to the analysis of those tasks, can help to understand if the user is progressing as expected in a more suitable way.

5 Conclusions

The approach presented in this article is a system based on mobile devices and QR codes that helps people with acquired brain injury in their everyday life activities. These people present damages in their brains (after a stoke, in example) so any capability may be affected. In this sense, these people usually present troubles in performing daily life activities, such as ironing or cooking.

We consider that mobile devices (such as a mobile phones) are appropriate to assist them in this kind of tasks because they are familiar devices and are almost permanently carried by the user. Their functionality has improved dramatically in the last years and now they are able to perform advanced computational tasks. They also allow multiple ways of interaction, by means of a keyboard, gestures or voice. And the information displayed on these devices can adapt to each task or the necessities of each individual user. For the recognition of tasks, the elements of the environment will be tagged with QR Codes, which are low cost and easy to integrate sources of information. Relatives or caregivers can create new QR Codes and print them for their immediate use in the environment.

With the combination of both elements (mobile devices and QR Codes) the system will provide interactive and personal manuals that will help users with acquired brain injury to remember how to perform simple routines. These manuals can be based on simple tasks related to a specific element (e.g. how to use an appliance) or more complex tasks related to a routine (e.g. how to iron a shirt or make the breakfast). They are also adapted to the necessities of each user and can change dynamically depending on the progress of the patient.

The interaction with these manuals can be monitored, so relatives and caregivers receive a full log of each execution of the patient. This way, we were able to analyse the patient progress as it was shown in the evaluation. From the data collected we can conclude that our system worked: the patient acquired a greater level of autonomy since he was capable to do the activity by his own, and even, he improved his times.

On the other hand, the evaluation carried out explored some other issues, such as the environmental factor. Changing user environment had an effect on user performance and his times raised. Once the user got accustomed to the new environment, he improved his times session after session. Although he seemed to be doing his best, the rehabilitation team decided to adapt the sequence to reduce the amount of guidance. This was a good decision, since he improved his times even more. This adaptation worked better for larger or more complex subactivities than shorter or easier ones.

From the data collected we were able to identify the tasks that took longer on average. After doing a particular study of each one along the different sessions, we conclude that, in some of them, he needed more time on early sessions but then, he experienced an improvement in his times, what can be related to a positive learning process. On the other hand, there were tasks that did not experience an improvement. In our opinion, this is caused by the nature of the task. This is, the task actually require a higher period of time to be performed regardless of the user knowledge.

In summary, this study allowed us to validate our proposal of adaptive manuals for people with acquired brain injury. Secondly, we discovered some limitations and special situations that affects to user performance. And finally, our main objective was achieved, since the patient who tested the application demonstrated that his was capable to do the activity by his own after fourteen sessions with our system.

Finally, the conclusions extracted from this study can be extrapolated to general AT systems, in terms of studying adaptation, environment and longest tasks. Adaptation, in this case related to a reduction in guidance, works better for larger or more complex activities. The environment affects to user's performance since she may need a set of sessions to get accustomed to it, so in the case of changing the environment, it is advisable the user is trained again with the system until it gets familiar to it.

6 Future Work

Experts in rehabilitation, doctors and therapists will describe these manuals, so an authoring tool is required. In this tool they should be able to configure the instructions, input methods and other features, such as language, color palettes, font sizes or flow of interaction.

Another improvement could be the addition of an adaptation engine that studies automatically the log and proposes the adaptation of an activity to a concrete user. We think this engine should propose adaptation in contrast of adapting it automatically, since the therapists must evaluate these changes before applying them.

The evaluation presented in this article included only one patient since we wanted to validate our system and extract some first relevant ideas about the characteristics of its application to this therapy. A new evaluation should include a greater number of patients with different clinical profiles and the progress in this therapy should be compared to the progression in others.

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