Therapist-centred design of NUI based therapies in a neurological care hospital

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Abstract—**Through a participatory design (PD) process with therapists at a neurological chronic care hospital that has no ICT based workflow processes we identified three main components where NUI technology can be deployed for physical therapy: patient stimulation, on-demand patient therapy tool control, and data logging and visualization. Based on our study, we created a scenario that encompasses these components for a specific physical therapy activity targeting head and torso movement for children suffering neurological disorders. The scenario includes a Kinect, large screen and mobile pervasive technologies controlling a game-like activity including data logging and visualization in a shared social intranet. Hospital staff liked the game-activity and logging, but expressed concerns about parallel use of technology. They also wanted to expand the use of the NUI technology in the therapy room leading to new scenarios that we are pursuing. We are using our participatory design process with therapists that are not tainted by the use of graphical user interfaces (GUIs) to establish scenarios where NUI designs can provide access to ICT tools to help us develop better NUI design principles.**

Keywords

NUI; Kinect; ICT; chronic mental health care hospital; physiotherapy;

I. INTRODUCTION

With the increasing use of Internet and ICT in recent years, it is natural to observe the union of health scientists with computer scientists in research and development of technological solutions that advance the current state of global health [1]. Thus, several studies [4,5,7,8,9,10,11] have been carried out in the application of ICT within hospital settings, with many different proposals, like: improving communication processes among hospital staff, providing more accurate diagnostic tools and treatments, assist in therapy processes, increase patient's medication adherence, and others. These efforts are categorized as part of the concept of e-Health that encompasses several initiatives to use these technologies in order to improve health processes. E-Health has been defined as the use of Internet and other technologies in the health sector to improve access, efficiency, effectiveness and quality of clinical processes used by health organizations, patients and consumers in an attempt to improve the health of patients [1].

FIGURE 1: Image of physiotherapy session at the hospital. Note that while attending one child the other child sometimes vies for attention providing an opportunity for a game-like therapy scenario that uses NUI technology.

Despite the efforts already made, much work can be done in improving healthcare processes with the application of ICT, especially in mental health care [2]. In this context, the project UNITY was created in the Laboratory of Advanced Interactions of the Federal University of São Carlos, which is being developed in partnership with a chronic mental care hospital, focusing on the transition of patients to live in society again [3].

The main objective of the project is to provide healthcare professionals with ICT tools that help them in their daily activities within the hospital such as in a physiotherapy session (Figure 1). This group of professionals, in particular, is not used to using graphical user interfaces (GUIs) or computers in their daily work routine, which creates new challenges for researchers in the design process [3]. However, they have begun to appropriate the use of their mobile phones into their workflow; thus, it presents an opportunity to leverage their ability to use pervasive, mobile technologies without having used GUIs. We used a participatory design process that allows us to incorporate their experience and skills to further push mobile and the NUI paradigm for their work, allowing us to avoid a bias found with the mouse/keyboard and GUI

paradigm. NUI technology holds much promise for allowing natural workflow practices to be supported by ICT. At this first stage of our research, we are looking to develop NUI design principles based on participatory design with the hospital staff.

From the PD process the research team identified a variety of processes that could be improved with the use of ICT. In particular, we identified one of the physical therapy processes that may be well suited to having additional tools based on NUI technology and mobile platforms to help with children with chronic mental illness. One important point we emphasize is that our intention is to create NUI design principles at this stage, rather than trying to improve their workflow significantly. This is because a successful NUI design should not interfere with the natural workflow. Further, if it is a successful NUI design, then the people using them should be able to easily find new ways to utilize the tools for changing their natural patterns rather than have it imposed upon them. Nonetheless, at our first set of PD sessions, we worked together with the hospital staff to identify where ICT could be helpful for them.

We describe some of the related work on NUIs and therapy in section II. Section III describes our design approach followed by the results and analysis of our participatory design process thus far in Section IV. Based on the major components identified, we illustrate the new therapy tool in a scenario in Section V with conclusions and future work provided in Section VI.

II.   NATURAL USER INTERFACES APPLIED IN THERAPY

With the launch of the Nintendo Wii at the end of 2006, a new wave of using motion sensors for low cost applications in electronic games emerged. Before long they were used for other types of applications, including health. Nintendo itself saw other applications for its technology, developing games of physical exercise (exergames) like Wii Fit, Wii Fit Plus and the Wii Balance Board peripheral, a weight and positioning sensor [4].

Since then, researchers and companies have been developing several applications of exergames and other therapeutic activities using these motion sensors. For example, Geurts et al., [5] using the sensor based controls of the Nintendo Wii, developed a series of exergames in the therapeutic process to help people with mobility disabilities. Geurts et al. conclude their study highlighting that they obtained satisfactory results regarding the capture of movements by the sensors, and encourage other researchers to try different therapy application for this technology.

Another product development recently that impacts NUI technology in health is the Microsoft Kinect, launched in 2010. Just as with the sensors of the Nintendo Wii, Kinect was initially developed for entertainment purposes as a peripheral for the Xbox 360 [6]. Kinect can capture 3D scenes and even identify and distinguish people who are within the range of it's lenses. Important for the research we are pursuing, one key element, as pointed out by [7] is that Kinect does not require additional peripherals to capture movements, giving considerable freedom to users.

Several researchers have been using Kinect and other motion sensors to assist in therapeutic activities and rehabilitation of people with a disability. Schönauer et al [8][9] explored the use of motion capture in the development of exergames to combat chronic pain in the back and neck. Vuong, Ingalls and Abbas [10] made use of Kinect in rehabilitation and therapy of patients diagnosed with Parkinson's disease. Again, the visual feedback is highlighted as being an important part of application use. The studies are still in early stages, the authors have done some tests with healthy people, but they believe that the results will also be useful for patients with the disease. Additionally, researchers have been working with Kinect for rehabilitation of children with autism, using entertaining games released for the Xbox 360 [11].

In Chang et al's Kinerehab project [12], they create a therapeutic application that uses motion sensors to assess whether the user is performing the activities correctly. Visual feedback is based on pre-recorded videos that show the movement to be performed, then the application stays in a standby mode until the user perform some certain movement properly, the application will only show the next exercise when the user completes the previous exercise correctly. Chang et al. report that they achieved high motivational rates among the therapists who participated in the project and the patients who underwent exercise. They cite the limitation of appropriate calibration of Kinect with people in wheelchairs as a factor that can negatively affect patients' experience in the use of the application.

Applications developed with these sensors are not restricted to rehabilitation activities. For example, [13] reports that some U.S. researchers are investigating the use of Kinect for identifying risks of mental illness in children. From the observation of some pre-defined behaviors, they are trying to develop an application that recognizes typical symptoms of mental illnesses that affect children. The studies are still in early stages but appear promising.

III.   THE DESIGN PROCESS

For this project, we have partnered with the Center for Integral Health Care (C.A.I.S.) "Clemente Ferreira", a special chronic care hospital for individuals with neurological and brain disorders where professional health staff are looking to facilitate patients' transitioning from the hospital back into normal society. The hospital has 3 floors with 6 wings with 1.700 patients and 650 professionals distributed throughout. The hospital has four distinct professional roles: administration, health professionals, maintenance and patients. We selected a group of six trained health professionals with extensive experience: 1 physiotherapist (15+ years experience, undergraduate degree), 2 nurses (20+ years of experience, nursing degree), 1 occupational therapist (15+ years experience, undergraduate degree), 1 social assistant, for our study as shown in figure 2a. Currently, at the hospital they all use a paper-based system for their primary workflow mechanism; they do not have prior experience with GUIs in the hospital. We believe working with these professionals provides an opportunity to skip directly to NUI's interaction, without passing by GUI-based thinking for our design process. Thus,

we chose a Participatory Design (PD) to include these professionals to avoid our own bias towards the use of keyboard and mouse interaction. Another challenging aspect is that the infrastructure in the hospital is very limited, causing spotty Wi-Fi and cell phone coverage limited the effectiveness of intra-hospital communication using these technologies.

In our design process, we adopted a workflow similar to that adopted in other contexts like ours, as reported in [14, 15, 16].

Participatory Design

We had two, 1-hour PD sessions spaced one month apart. Both sessions were performed at the hospital during normal workdays. The health professionals that participated in these meetings were selected by the hospital director, including a physiotherapist, an occupational therapist, a nurse, a psychologist, an administrative assistant and the director of the Child Neurology Center (CNC). The director of CNC did not participate in the second session.

First of all, we presented the general context of the project to the group and had them sign an authorization form allowing us to use their images, sounds and names only for research purposes, as specified by C.A.I.S. Clemente Ferreira Hospital Ethical Statement. After this, we used a survey to trace some of the group's profile: two professionals never used e-mail or any social network and never bought something via internet; two use iPods and demonstrated abilities with ICT; all professionals had contact with touch technology, mobile phones and web search; none of them had contact with gesture based technology.

In the first session, we used a play activity without digital technologies, using only paper, pen and images focused on elicitation of each individuals workflow (Figure 2a). To facilitate adoption of PD technique we provided a practical example to illustrate the play activity, that was intended for each professional represent their daily work routine and procedures. All the professionals, except the director of CNC, participated and presented a workflow sketch with their daily routine in a cardstock and all the group made comments. Describing these processes was a difficult task for the professionals due to these processes being tacit knowledge. As a result of this activity, we obtained 5 artifacts with the workflow of each professional; one of them is shown in Figure 2b.

The second session was a consolidation activity to represent a common workflow from all professionals (Figure 2b) and a single artifact was produced. During this activity the participants also worked collaboratively while they chose the images and drew on the cardstock, showing how they identified themselves with each professional and coworkers. We observed that they tried to identify themselves on the images that were similar to them.

All the artifacts generated during the PD sessions were consolidated by the research team to create a small set of scenarios that are used in the next stages of our PD as discussed below.

FIGURE 2: (a) Preliminary activities to explain PD process. (b) A PD artifact. The six professionals are the first people facing the camera in the upper left picture starting from the left.

Adjustment and improvement of our process

As previously mentioned, describing tacit knowledge is not an easy task, and health professionals had difficulties articulating their tasks at a sufficiently detailed level thus far to identify opportunities to insert technologies.

So we decided to have an additional two meetings at the hospital, but this time using other techniques: *in situ* observation and video recordings. This helped to elicit details on the therapeutic processes, in order to find clues about how NUI could be used to help them in processes described of scenarios.

Data analysis and creation of scenario with ICT

Using these new artifacts, the research team had a brainstorming session to identify where NUIs may be useful in the scenarios. From this brainstorming, we redesigned the workflow artifacts highlighting the information that was missing and generating a new set of workflow artifacts to present to the professionals.

After this, we had a new meeting with the health professional staff to get a consensus to confirm and complete the final missing information. We used a "fill in the blanks" activity to consolidate our proposal workflow interpretation.

Ultimately, we converged on the physical therapy scenario as our first target for introducing NUI and mobile technologies into the hospital.

IV.   RESULTS AND ANALYSIS

Description of Child Therapy

From this design process the research team could better understand where ICT can assist in the processes of the hospital.

Four major research opportunities were observed:

- The use of NUI to improve internal communication among the health professionals

- The use of a social network to promote empathy

- The applications of ICT in the literacy process of patients

- The use of NUI-based ICT to support therapeutic processes

This paper, in particular, focuses on the use of NUI-based technologies in support of existing physio therapy processes in the hospital.

During and after the participatory design and brainstorming sessions, we identified existing work practices to discover places where NUI technologies may best augment their activities. Our first target for NUI design focuses on a particular therapeutic situation. Specifically, often, there are two children that are in the therapy room together with only one therapist. When one child is being attended to physically, the other child is left on their own on the floor nearby. This child may try to get the therapist's attention, for example, by playing a "peek-a-boo" game while she is physically treating the first child. The therapist uses this situation therapeutically by playing along with the second child to help them develop physical skills, such as raising their head or moving their body, in parallel to the physical attention to the first child. More specifically, a typical therapy session goes as follows:

1. The therapist brings two wheelchair bound children (i.e. 5-14 years old) to the therapy room. The therapy room has a rubber floor for safety and has plenty of windows for providing a well-lit, pleasant environment for the children.

2. One child is placed on the ground while the other is being attended to by the therapist.

3. The attended patient therapy includes various exercises for relaxation and stretching of the fingers, hands, wrists, arms, toes, the soles of the feet, ankles and legs, with the patient lying supine (belly up) and making the patient have different positioning patterns, i.e. cross-legged, with semi flexed arms up, hands and fingers cupped facing up, with hands bent inwards along with activities to promote different types of movements adjusted to the patients development.

4. During the sessions, often the patient on the ground wants the attention of the therapist. If the patient has enough mobility, this can lead to playing "peek-a-boo" with that patient. The patient, i.e., Bruno, on the ground covers his head with a sheet, then the therapist says, "*Where's Bruno?*" The child then removes the sheet from his face. The child laughs and tries to look up and see her face again that helps with developing control of the trunk, head and related muscles.

The exercises are adjusted for each child based on how developed they are. For example, if the "peek-a-boo" game is too difficult for the child, the therapist may try other means to keep her engaged and trying to move. As part of the engagement efforts, the therapist often uses one child to help "bait" the other.

These sessions typical last 50 minutes and are done three times per week per child. At the moment, the progress of each child in managed adhoc with the therapist keeping track in her own way.

From the PD sessions and observation of the therapy, the researchers identified possible contexts in which technology could contribute to the current physiotherapy processes. The main concept that emerges was that 1) when the therapist needs to work with two patients in the same session, the patient who is waiting their turn could interact with a sensorial stimulation application, and, 2) the same application could be used to automatically log the patient activity during the therapy that would help the therapist monitor the progress of each patient.

Thus, during the PD conversations with the physiotherapists, it was decided to create an application that attempts to stimulate the movement of the neck and head of the patients, since this movement is important for the development of other movements of the body and balance of these patients.

NUI Scenario in Child Therapy

Based on the analysis from the last section, the scenario planned by the research team can be divided in three interdependent components:

- Stimulation application: responsible to stimulate the patient to perform certain movements indicated by the therapists; we are targeting a game-like environment based on Kinect for this.

- Session control: an application which allows the therapists to control the stimulation parameters according to the needs of their patients: we are targeting a mobile application for this to make it simple for the therapist to adjust on demand, in real-time.

- Data logging and visualization: capturing patients activity and giving appropriate feedback to the therapists about the progress and evolution of their patients; we are planning to leverage the Kinect data coupled to a server based data analytics coupled to mobile visualization for on-demand, mobile visual analytics.

Accordingly, the following scenario, shown in Figure 3, illustrates how we envision a system, called *Unity-Physio*, that encompasses the three main components for the therapists in this context.

Scenario: Using Unity-Physio to Stimulate and Track a Patient
Alice, the physiotherapist, brings Bruno and Carolina to the physiotherapy room, that is equipped with, Unity-Physio, a pervasive NUI based ICT system, to stimulate and capture the movements of patients, using natural interfaces based on gestures, videos and audio, that includes a large screen display, a Kinect 3D motion capture sensor connected to a server controlled by the therapist's smartphone/tablet.

Configuring the session: Prior to her arrival, (1) Using her smartphone, Alice set up the system to meet Bruno's needs for the time she plans to be working with Carolina. She did this by connecting to the hospital Social Intranetwork and accessing Bruno's records, including how his sessions in the therapy room went, as well as the therapeutic decisions that were made by others. On the Social Intranet, she discusses the options with her colleagues who are online.

She configures variables such as intensity, the visual and audible feedback stimulation in an effort to encourage him to exercise and strengthen his neck muscles. After the initial configurations,

In the therapy room: *Alice goes with Bruno and Carolina to the therapy room and, while she focuses on Carolina, activates the Unity-Physio profile calibrated for Bruno. When he is positioned in front of the television, (2) Unity-Physio triggers attractive air bubbles moving upwards in an aquarium on the screen as visual and auditory stimulus. Noticing that isn't responding so well to the settings, (3) Alice takes out her smartphone and re-adjusts the settings in real-time to make larger bubbles that last longer and have Bruno's face appearing in the bubbles and emitting joyful sounds when they burst at the top. Later, as she sees that Bruno is responding better now, she readjusts the setting to focus more on his lateral movement turning on Fishes that swim from one side to the other on the screen. Now that Bruno is interacting with the system effectively, Alice then has time and attention for Carolina. During the session, the Kinect is recording (4) video, audio, depth and body geometry that is added to Bruno's data on the server.*

Later, Alice is talking to her colleague at lunch about Bruno's progress. She (5) calls up the plot of the changes in his head movements over time with links to video of particularly salient movements on her tablet. With a swipe of her fingers, she zooms in on today's session and selects the video. They watch it together and her colleague notices that Bruno has moved to a new stage of development, so she adds an audio comment along with some ideas about settings of the Unity-Physio to help Bruno crawl, sit and walk.
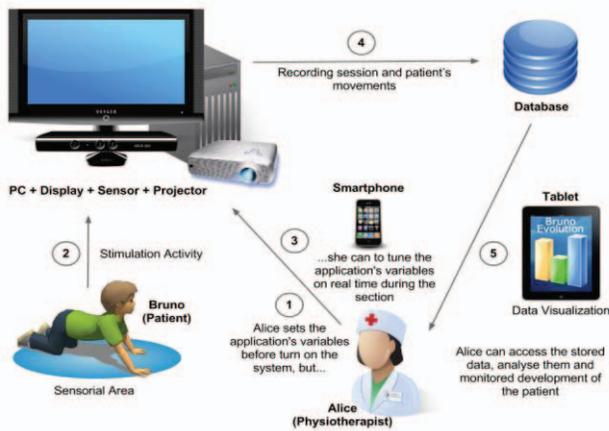

FIGURE 3: The proposed NUI based ICT scenario

We presented this scenario to the physiotherapists. They liked the ability to measure head movement and, further, requested torso measurements as being particularly useful. Though, when they focus on torso movement therapy, they only have one-on-one sessions requiring a different approach to the game-like activity added to the Unity-Physio system. They also liked the ability to tune the activity on demand, however, recognized that doing that through the smartphone at the same time as they are doing physical therapy with a child will be a challenge. We think that this may be an appropriate time to use gesture or voice control of the activity parameters that could be done with the Kinect. On this last point we have piloted a Xbox Kinect based speech recognition system adjusted to have English-like commands easy to be adopted by the Portuguese speaking therapists.

Data visualization requires close coordination with the therapists needs. This is a significant challenge. Using the Kinect, there will be a large amount of video, audio and geometry data (with noise) that the physiotherapist will have access to requiring effective analysis and management tools [17]. This is part of our next steps for developing this scenario.

V. CONCLUSIONS AND FUTURE WORKS

In our PD sessions, we were able to observe that working with mental healthcare professionals who have little experience with graphical user interfaces (GUIs) provides us good feedback and insights when working with designing workflows using a NUI paradigm. We found that their lack of mouse and keyboard bias allowed them to accept and understand better what natural interfaces are and how they work, improving their overall acceptance of the inclusion of technologies in their usual work processes, in contrast, to their verbally stated aversion to introducing a GUI environment. However, the participatory design sessions were less than optimal because the healthcare professionals were not able to fully understand what benefits NUI based ICT brings to their daily workflow coupled to the common phenomena of non-experts not knowing the limitations of a particular technology.

To mitigate some of these issues, during our PD sessions, we began with presenting scenarios in the physiotherapy room. Then, together, we identify where the usual physiotherapy sessions with their patients can benefit from the addition of NUI technology. Thus, we are presenting our intervention as augmentation of their existing processes coupled to their appropriation of mobile technologies. Thus, the main goal is not to change their existing processes, but rather give them additional tools to integrate into their regular workflows as they find appropriate for their patients.

We continue developing higher fidelity prototypes, using a large display and the Kinect sensor in the therapy room and observe the interactions between the therapists and the device. Already, we have placed a large display (46:") in the therapy room and received very positive feedback from the therapists as it stimulated their imagination. We are planning to simulate a therapy session with the hospital staff and the research team to better understand which situations, exercises and therapy movements the Kinect sensor will be able to register properly so we can develop the game-like activity effectively.

At this stage of the project, we are encouraged by the response from the hospital staff that NUI based interaction using mobile devices, large displays and inexpensive, non-invasive sensors can dramatically improve the performance and effectiveness of the professional's work to help their patients.

From the analysis of the PD outcomes, we identified two distinct pathways for moving forward in the research. On one hand, it is clear that the PD identified benefits that ICT can bring to the therapy setting with NUIs helping make the inclusion of the best practices for using ICT simpler. On the other hand, a second pathway emerged that emphasized that we are seeking to identify and measure new NUI design principles by taking advantage of the way this particular non-GUI user group looks at their workflow through a paper-based lens. From this perspective, we are using the PD with the hospital staff to identify places where we can bootstrap NUI designs to include ICT mechanisms into their workflow with minimal

disruption, as that is one of the objectives of NUI, so that we can then determine whether these mechanisms become appropriated for changing their natural workflow by the hospital staff themselves, rather than from a techno-centric design to introduce best-practice using technology. By measuring this appropriation of NUI to change their workflow we expect to determine which NUI elements are most effective. We are pursuing this latter pathway currently.

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