Active Surfaces: a novel concept for end-user composition

Erik Grönvall, Patrizia Marti, Alessandro Pollini, Alessia Rullo
Communication Science Department,
University of Siena, Italy
marti@unisi.it, {gronvall; pollini; rullo}@media.unisi.it

ABSTRACT
This paper describes the design process of a modular system for supporting physical and cognitive rehabilitation in the swimming pool. In such an environment, the therapist is called to creatively adapt rehabilitation protocols to the enhanced ability of the patients, often reacting to emerging behaviours enabled by the water. Therefore a strong technological requirement for such environment is to develop a modular system that can be configured and modified "on the fly" during the activity, exploiting the therapeutic properties of the water. To satisfy such a requirement the system of Active Surfaces has been developed. It consists of a number of position aware floating units, called tiles, able to communicate each other and to provide visual, acoustic and tactile feedback. By combining the different tiles the therapist can easily configure the dedicated tasks for the various typology of patients. The concept has been developed following the Palpable Computing approach, an innovative design paradigm complementing key features of ambient computing, such as invisibility and end-user composition of devices, with dual features (e.g., visibility and decomposition) that enable users to navigate, configure and influence the computing system.

Author Keywords
Ambient computing, Palpable computing, end-user composition, programming by example.

ACM Classification Keywords
Interactive System, Interactive environment, Design studies, User-centered design, Evolutionary prototyping, Advanced technologies, Portable devices, Wireless Communication, Sensors

INTRODUCTION

The notion of ambient computing has been consolidating focusing on the design of distributed, pervasive and reactive systems able to communicate with the users and to continuously adapt to their needs and expectations. However the users must always remain in control (Schultz, Corry, Lund 2005). Balancing transparency and automation with awareness and control is the goal of PalCom (PalCom, http://www.ist-palcom.org), an European project that aim at developing an innovative design approach called Palpable Computing. Palpable computing complements key features of ambient computing systems, such as invisibility and end-user composition of devices, with dual features (e.g., visibility and decomposition) that enable users to navigate and influence the computing system (Schultz, Corry, Lund 2005). The paradigm purposely addresses the way in which humans meaningfully interact with distributed computational systems available in the environment. Palpable computing aims at supporting user control by composing and de-composing assemblies of devices and services. The assemblies are configurable by the user depending on the context of use. Consequently, these assembled systems should support the continuous attribution and negotiation of meaning through interaction.

The notion of palpability also embodies the concepts of graceful degradation and inspection: palpable systems can support resilience in case of functional breakdowns. If part of the system fails, still some functionality should be available and working. Inspection allows the user to examine the current state of a system or component and to reconfigure the system accordingly. If a system is subject to degradation, it should be able to communicate its new state. A typical scenario for palpable computing could be the following:

You are on a train with a friend working on your laptop. You also have a camera-equipped mobile phone that unfortunately does not work any longer. Nowadays it is impossible to use the camera and other services in the phone, while the screen is damaged. Here a palpable mobile phone could prove useful. If you could define an assembly connecting the screen of your computer with the camera in the mobile phone, the camera could still be used, even if you cannot browse or see the pictures on the mobile display. If your friend needs to control his email, he could communicate over Bluetooth and GPRS, simply using the mobile as a network interface, then controlling the actual connection on his laptop. In this way he could still use the telephone communication capabilities disregarding the broken screen.

Thus palpable technology can provide the users with the opportunity to overcome some failures of the system by relying on the working components. System resilience and re-arrangement of the available resources are key features of palpable computing.

These themes become crucial if applied in critical domains such as health care and rehabilitation. In this paper we will address this discussion presenting a design study in which a tool supporting rehabilitation practice has been developed embodying some of the qualities of the palpable computing. Therapists working in cognitive and physical rehabilitation with disabled patients usually experience their job challenging and demanding. Every time the therapist starts a treatment she has to define a specific program and ad hoc solutions with the aim of designing a rehabilitation intervention that could adapt to the individual patients' needs. Thus, the work of the therapist is mainly characterized by creativity both in designing engaging activities and suitable tools.

Furthermore, rehabilitation in the water poses specific and interesting research issues both for the development of digital technologies and for the therapeutic practice. Indeed wireless connection, perceived feedback, robustness and stability of the system are continuously challenged by the environment, whilst the quality of the water creates a safe context where impaired people can move autonomously, something they cannot do elsewhere.

Active surfaces is the concept developed for rehabilitation practitioners being a support for physical-functional and cognitive rehabilitation treatments in a swimming pool setting. The system consists of a number of tile components. They constitute a network of physical (and software) objects communicating each other, exchanging data and able to recognize their relative positions in the space. These features support the construction of meaningful configurations of different tiles. Each configuration can be conceived as an assembly of components. The therapists can configure these assemblies by programming by examples. They can save successful configurations, keep memories of previous configurations and generate new assemblies to support patients' specific needs. Each tile acts as a building block whose behavior can be defined using a library of contents (images, sounds, pictures…). In this way the system provides the therapist with the possibility to design specific tasks and activities for the patients and to integrate cognitive training and physical rehabilitation. In this paper a design study we will reported on the initial implementation and testing of the Active Surface concept in the swimming pool setting. The work has been conducted following a co-evolutionary method (Marti, Rizzo 2003; Marti, Moderini 2002). The approach integrates participatory design with creative concept design, using different typologies of scenarios for converging ideas into solutions. The early phases of our fieldwork have been devoted to understand the activity, to define requirements and to collect best practices. On this basis, the concept of the Active Surfaces has been developed, capitalizing on participatory design activities, creative workshops and following the Palpable Computing approach.

RELATED WORK

Systems of modular tiles have been explored in many research projects along the last few years. A benchmarking activity has been held to provide our design process with a frame on current projects on tiles, used technologies and explored prototypes. This early investigation of the field highlighted the strengths of each projects mainly based on characteristics like physical features and material (Sony DataTiles) (Rekimoto, Ullmer, Oba 2001); I/ O systems (Playware and Tangible Interfaces) (Gorbet, Orth, Ishii 1998), communication (Z-Tiles) (Richardson, Fernström 2003), configurability and position recognition (u-Texture) (Oshawa et al. 2005).

In particular the u-Texture pervasive application was of inspiration for our concept development. u-Texture is a self-organizable universal board that enables to change its own behavior autonomously through recognition of its location, its inclination, and surrounding environment by assembling them physically. The other work that mostly informed our process is the Playware developed by the Southern Denmark University. The tangible tiles behave as building blocks in which the coordination of primitive behaviors through physical modules, such as a tile, together with the interaction with the environment, decides the overall behaviour of the system.

The following paragraphs will describe the peculiarity of the Active Surfaces context of use and the specific challenges we tried to explore in the design process. The major focus on end-users and Palpable qualities (such as understandability, end-user composition, change/ stability) makes Active Surfaces differentiating in respect to other systems of modular tiles.

THE REHABILITATION PRACTICE

Physical and cognitive rehabilitation represents a complex whole of practices and methodologies. The treatments protocols and the techniques, although representing the foundations of this discipline do not embrace all the aspects involved. Rehabilitation is a transversal process since it intervenes in the treatment of different typologies of patients, sometime in conjunction with other kinds of medical treatments. The patients can be temporary or permanently affected by diseases or impairments; they differ by age, problems and attitude toward their situation. Thus, each therapeutic session represents a unique and novel experience.

These initial considerations inspired a deeper understanding of the rehabilitation work practice. Our investigation mainly concentrated on the rehabilitation of disabled children performed at the Rehabilitation Unit at 'Le Scotte' Hospital (Siena, Italy) and at the public swimming pool in Siena. In our analysis we concentrated on these two contexts, investigating how their different features shape the work practice carried out by the therapists. The fieldwork included phases of observation, video recording, interviews and activity analysis.

Figure 1. Participatory design at the Rehabilitation Unit

The *psychomotor rehabilitation* therapy supports the development of higher cognitive and physical functions and helps to recover or improve individual capabilities.

In many cases (e.g. Hanart Syndrome, Moebius Syndrome, Angelman Syndrome) there is no agreement on the therapeutic protocol that should be used to aid in the development of even very basic skills (e.g. communication and motor coordination). Thus the modality in which the therapists approach the rehabilitation is based on a process of trials and errors, trying to configure 'on the fly' their therapeutic aids or adapting the existing tools. When something proves to be successful in a particular case they assimilate this as a best practice to be re-used in other situations.

For ***cognitive rehabilitation*** therapists use cards, pictures, photos, software applications and everyday objects in order to improve cognitive skills such as image recognition, image matching, visual memory and procedures. On the other hand, the development of motor abilities requires repetitive exercises to sustain coordination, balance and movements.

In their current practice, motor and cognitive rehabilitations are mutually separated. Specific tasks and tools are designed for the motor physiotherapy; whereas other tasks, aids and tools are defined to support the acquisition of cognitive skills. The two activities are usually never integrated.

The swimming pool represents a privileged environment for rehabilitation. At the public swimming pool in Siena a volunteer association provides training and group activities for disabled people. The swimming pool is a powerful setting from many respects., The water supports the body and gets the weight off the joints. Movements within the water are easier and less painful. In fact, water is a great 'equalizer' for disabled people who find that while inside the water, their movements are easier and less different from those of non-disabled people.

The subjects involved in these rehabilitation initiatives are both children and adults with different disabilities such as Down syndrome, cognitive and physical impairment, microcephaly, developmental delays and autism. Most of them have motor-physical disabilities and the water helps them to better coordinate their movements and to autonomously keep their balance. Water may also aid in the control of respiration, the understanding of space-time relationships and the perception of the self-motor activity. This particularly because of the global sensorial stimulation. Physically impaired people can be supported in structuring basic body schemas through freely moving in the water.

The trainers who assist the children in the swimming pool we studied, are all volunteers, without any specific previous experience in rehabilitation. The activities they perform today are not structured and non specific therapeutic objectives are stated. One of the main goals of these activities is the socialization. Therefore, the patients mainly interact with each other in different spontaneous ways. Usually there are few tools such as boards, bracelet, and balls commonly utilized for the swimming training that are used also by the impaired patients.

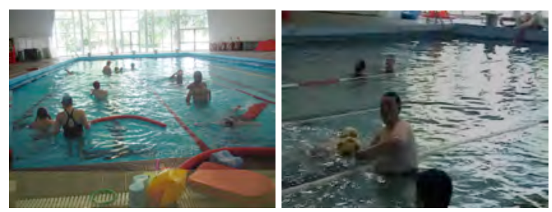

Figure 2. Group activities for disabled people

An intense period of observation in the swimming pool made us capturing some peculiar features of the rehabilitation practice.

On-the-fly configuration and creation of assemblies. A first consideration is on the rehabilitation activity. Dealing with continuously changing conditions and rehabilitation demands, the therapists should always find new solutions to adapt their tools and the environment to the patients and to capture their attention along the session. Consequently a core characteristic is that the tools have to be easily re-configurable to adapt to this evolving situation.

Dealing with failures and degradation. The therapists usually deal with dynamic settings and changing conditions. This implies the ability of rearranging the available resources even if in case of degraded performance of the socio-technical system (tool, environment, people, technology).

The possibility to re-use the assemblies and keep trace

of the best practices. This is the possibility to define best practice and to re-use a configuration of objects and settings, creating a toolbox containing the know-how concerning creative usage of the existing therapeutic tools.

Combination of cognitive and physical rehabilitation. The lack of integration of the physical and cognitive rehabilitation represents another aspect of the rehabilitation practice of today. The cognitive tasks are usually quite boring for the children and they quickly get tired and lose attention. On the other hand, motor rehabilitation is very demanding at a physical level and is based on repetitive sequences of actions often perceived as tiring and not engaging.

At light of these considerations, the swimming pool presents a strong potential.

The properties of the water can enable new opportunities for rehabilitation. The reassuring and calming qualities as well as the facilitation of body movements create a pleasant setting in which cognitive tasks can be easily combined with physical ones.

ACTIVE SURFACES

The concept

The fieldwork analysis and the different creative sessions with the stakeholders have informed the concept generation phase along the design process. We tried out different creative methods, like brainstorming sessions and attribute listing in order to produce concepts in collaboration with the stakeholders.

The main idea is to rethink the environment of the pool, making it a place for rehabilitation and play activities. Indeed the swimming pool is designed mainly for swimming, not for walking or running for example, as required by most of the rehabilitation activities. Our design process aimed at re-considering all the dimensions of the swimming pool (bottom, surface, vertical walls) and to invent new activities.

From an interaction design perspective the goal is to design new activities for the rehabilitation by designing enabling environments and tools. The Active Surfaces is the concept that embodies these issues.

The Active Surfaces concept accounts for the need for configurability, constructability, modularity, physicality and creativity in rehabilitation practice. 'One' Active Surface consists of a tile, measuring 30*30 cm. This is the standard tile that can be used for the different tasks. Each Active Surface is thought of as a modular unit that can communicate with the others by the six sides. The tiles are in fact able to recognize their relative positions. Then there exists a privileged tile: the Assembler Tile which is used by the therapists to program the other tiles. A number of tile components can be logically assembled (using the Assembler Tile) and can constitute a network of physical (and software) objects that communicate and exchange data. Many qualities of palpable devices are embodied in the Active Surfaces concept.

Active Surfaces are conceived as the modular units of an assembly. The Active Surfaces constitute assemblies on different levels: on the logical level the therapist can define what the rules are and what the purpose is. On the functional level the user can mark out the relations and the sequences. Eventually, on the physical levels user can introduce new affordances for building / rebuilding the surfaces. Thus Active Surfaces offer a valuable example of physical construction / deconstruction of components. In that way the physical construction of assemblies (ref. Ingstrup, Hansen 2005) provides end-users (i.e. the therapists) with control of the system behaviour and adaptation to the context.
To support *end-user composition*, the Active Surfaces is also complemented by a Migrating UI browser mechanism developed within PalCom project at the University of Lund, for programming the rules and the behaviours to be instantiated on the tiles. The therapist creates patterns by physically building tiles' sequences.

The tiles address also *scalability* and offer an opportunity to produce scalable solutions still relying on low-level resources management. Furthermore, the understandability of the system can be guaranteed by balancing between system automation and therapist' (i.e. user) control. Even meeting the requirements of ambient computing, the tiles have to preserve the *understandability* and support the users to maintain control on the technology.

Flexible ad-hoc networks support the connections among single devices where each tile preserves its own identity thus dynamically seeking for available tiles in the vicinity. The tiles continuously inspect what communication processes are taking place at the moment looking for specific connection on all its sides. When one tile starts to fail the communication the sequence is still guaranteed by the other tiles. Standing the persistence of their identity, the tiles dynamically recognize the available ones to maintain the pattern. The therapists can thus manage the activities even in situation of system *graceful degradation.*

The Active Surfaces also enables the exploration of the relation between *change/stability* in configuring the tiles. In fact the assembly's behaviors are instantiated in physical configurations that can be saved, reused (also in part) and instantiated in different physical patterns.

The construction and configuration of the different tiles and how they relate to each other is done through *physical programming or programming by example*. It is the physical programming that allows the therapists to work with the tiles, creating advanced activities without actual programming or computer skills. In fact, programming by example can prove to simplify some very complicated programming tasks through the physical manipulation and the constraints (and affordances) a 'real' physical object provide through its interaction.

She can show the right pattern (sequence) to the system and record (save) the configuration by using the assembler tile. Being a flexible system it has to guarantee a proper level of *persistence* as well. The dynamics between configurations' change and stability may address the future practice of rehabilitation and the way in which the Active Surfaces could support it.

Evaluation of the concept

Active Surfaces concept have been put through a number of Wizard of Oz sessions and the feedback from these activities informed the iterative design process and the construction of the interactive prototypes.

The Wizard of Oz has been used as a design method in order to explore how people use ubiquitous computing and carry out complex interactions. In Wizard of Oz session the user can experience interaction with working system, even if the responses of the system are activated by the designers who play the role of the wizard. (Erdmann, Neal 1971).

In these sessions we placed the tiles on the ground (or the bottom) and on the wall (or the edge) of the gym and of the pool. The tiles have been explored mainly as components to be used in physical assemblies.

Figure 3. The Wizard of Oz sessions at the swimming pool

The children were engaged in a follow-the-path task in both horizontal and vertical configurations. The 'follow-the-path' task is based on guidance and feedback from the therapists. For the horizontal configurations we tried with surfaces on the bottom of the pool. Tiles were placed on a transparent surface through which they were fixed in the same positions. Patients have to follow a path made up of tiles coloured the same or following a shown model. During the Wizard of Oz sessions in the pool several wizards played auditory feedbacks from outside the water while other researchers, acting as therapists, supported patients in accomplishing the tasks.

We used low fidelity mock ups that embodied some (initial) physical features of the tool. In this way we assessed properties like weight, size, materials and possible uses.

End-user composition: concept scenarios

The Active surfaces concept was refined through an iterative scenario-based design process. Indeed scenarios were used in different phases of the design process since they are effective for structuring data gathered through activity analysis; for envisioning the system role and functionalities and finally to assess and validate envisioned solutions.

Along the different phases of the work analysis we used scenarios to evaluate, together with the stakeholders what we understood of their work, how the defined concepts could suit their needs and to show possible uses of the final tools. Scenarios themselves were used as design objects that have been evolved along the design process, being created, refined and also sometimes dismissed.

In the following part two concept scenarios will be presented to explain how the Active Surfaces enables end-user (therapist) composition.

Indeed, the tiles act as building blocks and have different reactive behaviors in relation to the environmental changes including different input from the users. Each tile provides a visual, acoustic or tactile feedback, this in order to aid the patient accomplishing the tasks and to guide her during the interaction.

Designing a new game (programming, discovering and loading)

The therapist Laura decides to use Active Surfaces as a tool for spatial orientation acquisition and procedural memory skills with a patient with cognitive and physical delay. Through a simple interface Laura defines different activities or games by setting general rules. She configures interaction patterns defining when, along the therapeutic activity, different input and output should occur. The rules are now downloaded to the assembler-tile.

Laura combines some of the tiles in a specific pattern. She attaches the assembler tile to the sequence of tiles and they initiate the discovery of the available tiles exploring their relative position. The Assembler tile meanwhile passes the game rules into the different tiles. She now removes the Assembler tile and the game begins. At the same time, the constructed shape of the tiles and the rules used are saved into the assembler tile. Laura can now change the physical configuration of the tiles, thus changing the activity by simply re-arranging the tiles and re-attaching the assembler tile.

Re-using pre-defined game (saving, flexibility and versioning)

The therapist Alessia is now looking for one specific Active Surfaces configuration she designed a few weeks ago. She uses the UI to browse among the configurations previously saved and stored (via the Assembler tile).

She finds the desired game and plans to use just a part of

the saved configuration, meaning reusing the same behaviour with a completely new physical combination. Alessia sets up the connections among the tiles' building the sequence. In that way she may experiment and try games through re-using pre-made behaviours in novel physical configurations. The rules (behaviours) have now been instantiated in the new pattern assuming different meanings for the interaction.
The therapist now wants to save also the designed configuration for later uses, so that each step does not have to be created manually the next time. Configurations can be saved and reactivated later also by different therapists and for different therapeutic goals.

By means of scenarios and participatory design sessions the concept also has been revised and refined. The knowledge produced in these workshops with users has informed the next phase of the design process: the prototyping. In the meetings at the hospital we began to envision features of the application such as input and output systems, communication modalities and configurability. We addressed these issues trying to figure out the needs of the stakeholders asking for comments and suggestions at each iteration cycle.

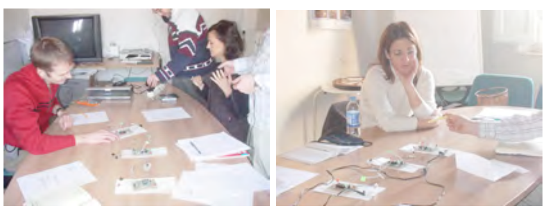

Figure 4. Participatory workshop on input, output, configuration and communication support

During these sessions we decided to focus on floating tiles to proof the concept with the early prototyping. It seemed to be more promising for consolidating the composition dynamics and understanding how it could impact the work practice.

EMBEDDING ACTIVE SURFACES

Probing prototypes

We adopted a step-wise approach to transform our concept into early mock-ups and then into working prototypes. In this sense, traditional Participatory Design and eXtreme Programming methods have been integrated in the development phase fostering a creative process with the stakeholders.

A number of low-fi prototypes have been developed to verify the different assumptions, the potential design solutions and the integration with the swimming pool setting. This work has resulted in more mature prototypes that have been assessed by the stakeholders along the evaluation process. The users have been able to comment on functionality, look-and-feel as well as been able to use 'semi-working' prototypes in a way that is not allowed by the traditional Wizard of Oz approach. In reality, some of the prototypes turned out to be easier to develop then setting up the Wizard of Oz sessions.

Finally two more advanced prototypes where developed in parallel. The first had limited functionalities, but it was sufficiently working to be more easily adapted as new user requirements emerged. The second one was closer to a high-fi prototype built on the final target platform. The latter is now under development and meets the specific requirements regarding execution speed and flexibility that is needed in the final system.

PoolSim software prototype

In order to explore more deeply the outcomes emerged from the Wizard of Oz sessions we developed a Java application (PoolSim) as a horizontal prototype in order to test some basic behaviors of the Active Surfaces.

PoolSim shows basic behaviors like location awareness, colour and size recognition and more advanced features of the concept like graceful degradation as well as dynamic communication among the tiles (Figure 5). PoolSim was a tool used to try out our design ideas on the screen, to get a feeling of how the tiles could work, both simulating new games and also testing different communication strategies. It has been particularly effective the simulation of the inspectability while the degradation of some components. It has shown the peculiarity of Active Surfaces in respect to other tiles modular technologies (i.e. Z-Tile, u-Texture and Playware).

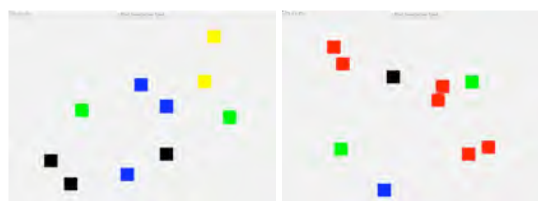

Figure 5. Screenshots from the Java PoolSim application

We used the PoolSim application in brainstorming sessions with the therapists at the hospital and at the public swimming pool. Examples of therapeutic activities were defined and were submitted to a refinement process.

Working prototype – Simple Model

The feedback from all the previous design made us develop the first actual 'tile' prototype (see figure 7). The development was based on the Basic Stamp 2 micro controller. Due to the constrains in the processor power and functionality, we limited this tile-prototype to communicate on two of its six sides. A simple communication protocol has been implemented so that the tiles can communicate and understand when they are placed in a correct sequence. When correctly located in relation to the other tiles, a light feedback is provided. This through a number of PowerLeds connected to the micro controller.

The outcomes of the trials with the prototype in the swimming pool indicate that the physical features of the surfaces are strictly dependant by the context of use. At this point we started to investigate the different materials that could be used for the casing, assessing how they worked in water, how the patients and the therapists in the pool perceive them and how they could reinforce the different rehabilitation activities.

The case needs to be fully watertight but still fairly easy to open, to access batteries for recharging as well as reprogramming the micro controller and to allow for changes that emerged during the trials.

We also tried out different communication possibilities, experimenting which different technologies would be suitable to use within a swimming pool, both on the water surface as well as on the bottom. We learned that Infrared communication (IR) could fit our needs.

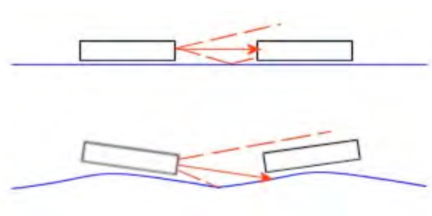

Figure 6. IR communications on the water waves

The IR also turned out to work well even while there are small waves on the surface, this since the IR emitted light (for the transmitter we up to now have been using) is spreading quite widely and due to water reflection. This is illustrated in figure 6.

The different envisioned activities seem to be based upon two different communication needs; the direct physical contact between the tiles and ~70 cm distance communication (above water). These seem to cover the needs of the end users involved in the rehabilitation activity. For the case colored materials should be used instead of transparent ones in order to provide users with consistent input for the activity. Transparent or blue surfaces may mislead the perception of the users being too similar to the edges of the pool or appear ‘hard to detect’ due to the reflections in the water.

Figure 7. Simple working prototype under construction and final result

One important requirement indicated by the therapist is that the patients should be able to both take two tiles at the same time by opening their arms and to physically snap the devices in order to fix them in a pattern. While correctly connected, the tiles can give visual feedback through red lights easily perceivable in the swimming pool. The prototyped tiles are characterized by the opportunity to apply layers on the top where different surfaces and materials can be attached as input for the activities, e.g. different surfaces can provide different tactile experiences to the users or parts of images can be composed to render the complete picture.

Activity Scenarios and early testing

The prototype we developed has been used for early exploratory tests with the targeted end-users, both the therapists and the patients during the current rehabilitation sessions in the swimming pool. The main activities we designed are based on the creation of sequences by just using three tiles. The activities were envisioned in the participatory design session with therapists and trainers relying on their current practice and on the expected potentials of the Active Surfaces. The exemplar activity scenarios presented below describe the game performed in the pool with different patients. The tasks have been tailored on the specific needs of the disable people. In fact we involved in the activity children with visual and physical impairments and or patients affected by Down syndrome.

Scenario 1: Image composition task

The therapist is designing an activity based on image composition (Figure 8). Each tile has a surface attached on top of it that is (re) movable in order to set different games. In this task each of the three surfaces has a part of the images that the children have to compose. The composition consists of placing the tile in the right sequence. The images to be composed are a circle and a star.

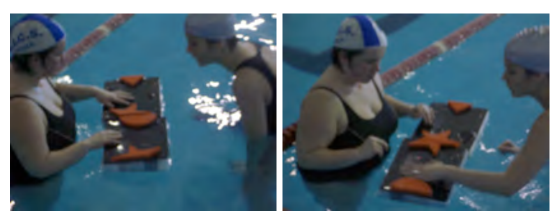

Figure 8. Image composition activities utilizing the Active Surface prototype

The parts of the images offer the affordances for the patients to accomplish the task. The side area of the surface shows the half of a complete image or symbol. Furthermore, a visual feedback occurs step by step, each time the tile is positioned in the correct order. This was designed in order to provide a progressive and coherent feedback during the creation of the sequence.

Scenario 2: Texture based task

The therapist is using Active Surfaces in order to design a rehabilitation game based on tactile experience (Figure 9). This activity is mainly thought for visually impaired patients. The therapist wants to stimulate the different sensory channels both providing specific inputs and appropriate feedback, such as vibration.

Figure 9. Tactile exploration

Thus she attaches three different surfaces made of woods of different dimensions on the top of the tiles. Using woods with different sizes, the textures provide the patients with diverse tactile perceptions. The goal of the activity is to create the sequence from rough to smooth. When the right tile is appropriately placed in the sequence, it vibrates to provide the patients with positive feedback.

State-of-art

During this exploration phase of the first prototype, we learned and defined the requirements for the final prototype developed by the University of Aarhus within the PalCom project. Each tile has to suit technical requirements such as response time and communication robustness and the need to run a framework that supports the features of palpable computing. The PRE-VM (Schultz, Corry, Lund 2005) is the language neutral virtual machine developed within the PalCom project in order to support object-oriented languages.

Pre-VM provides an execution platform for components to be embedded in physical devices and run in microprocessors as it is in Active Surfaces. Core PalCom functionalities such as communication, discovery, dynamic assembly, inspection and recovering degradation are implemented as components running on the virtual machine.

Each tile will embed the functionality as follows:

- It acts as an autonomous component, while being aware of its surroundings.
- During the activity the therapist can change the behavior of one or many tiles, responding to new therapeutic needs.
- A number of tiles can be assembled to create new or altered activities, also during the actual rehabilitation activity utilizing physical programming.
- The assembly can be physical and/or functional, allowing for different games and activities.
- If a tile starts to failure, it will communicate its new state to the others in order to allow system recovery. In this way graceful degradation shall be initiated allowing a continued rehabilitation activity.
- Although the tiles lack an active display, each tile can be equipped with an image or symbol that is attached directly to the top of the tile. In each direction, alongside the top borders, there will be rows of light emitting diodes to signal system and game states.

DISCUSSION

Our concept of Active Surfaces elaborates on a new challenging view of the rehabilitation practice. The concept addresses scenarios of fundamental lack of support for the therapists in treating disabilities. The Active Surfaces aims at offering opportunities for the therapists to appropriate their work practice by developing and building knowledge and creativity.

The scenarios we developed are based on the idea of end-user composition, configurability and control. In particular, users appreciate the idea of being supported by ready-at-hand technology, programming by example and system resilience. The Active Surfaces provides them with the possibility to improve the day by day rehabilitation practice.

The concept elaborates on a new challenging view of construction complemented with deconstruction of physical assembly. The therapist is asked to manipulate and physically configure the tiles while the dynamic and self-configuring discovering of components occurs. Re-configuring the system takes place at two different levels: the possibility to design specific activities; the possibility to re-arrange to available resources when there is a failure of the system. Thus, Active Surfaces makes the inner state of the system transparent providing a novel concept of user control.

The therapist can adapt the technology pursuing extreme changing and flexibility beyond system stability. In that way there are situations where total control is desirable, but it has always to be complemented with sense making and meaning attribution of events.

ACKNOWLEDGEMENTS

Thanks to Laura Cardosi, Maria Grazia Burroni and the therapists at the Functional Rehabilitation Unit of the "Le Scotte" hospital, Siena, for their open-minded collaboration and continuous support during fieldwork and participatory design. The research was part of the EC IST PalCom project.

REFERENCES

Erdmann, R.L. Neal, A.S. Laboratory vs. field experimentation in human factors. An evaluation of an experimental self-service airline ticket vendor. *Human Factors, 13*, 1971. pp 521-531

Gorbet, MG. Orth, M. Ishii, H. Triangles: tangible interface for manipulation and exploration of digital information topography. *Proceedings of the SIGCHI conference on Human factors in computing systems table of contents* Los Angeles, California, United States, 1998.

Greenbaum, J. Kyng, M. Design at Work. Hillsdale, NJ: Erlbaum, 1991.

Ingstrup, M., Hansen, K. M. Palpable Assemblies: Dynamic Service Composition for Ubiquitous Computing. *Proceedings of the Sevententh International Conference on Software Engineering and Knowledge Engineering*. Taipei, Taiwan, Republic of China. July 2005.

Marti, P., Rizzo, A. Levels of design: from usability to experience. *HCI International 2003, 10th International Conference on Human - Computer Interaction*, Crete, Greece, 2003.

Marti, P. Moderini, C. Creative design in safety critical systems, *Proceedings of ECCE 11*, Catania, Italy, September 2002.

Ohsawa, R. Kohtake, N. Takashio, K. Tokuda, H. Software architecture for self-organizable universal boards. In *Software Architectures for Self-Organization: Beyond Ad-Hoc Networking Workshop at The 3rd International Conference on Pervasive Computing (PERVASIVE 2005)*, May 2005.

Playware http://www.adaptronics.dk/Projects/index.html

Rekimoto, J., Ullmer, B., Oba, H. DataTiles: A Modular Platform for Mixed Physical and Graphical Interactions, *CHI2001*, 2001.

Richardson, B. Fernström, M. Network and Control Protocol for a Self-Organising Sensor Network. *Proc. CCCT,* 2003.

Schultz, U.P. Corry, E. Lund, K. E. Virtual Machines for Ambient Computing: A Palpable Computing Perspective *Proceeding of ECOOP 2005 Object Technology for Ambient Intelligence Workshop*, Glasgow, U.K., 2005.

Svensson,D. Magnusson,B. Hedin,G. Composing ad-hoc applications on ad-hoc networks using MUI *Proceedings of Net.ObjectDays, 6th Annual International Conference on Object-Oriented and Internet-based Technologies, Concepts, and Applications for a Networked World*, Erfurt, Germany, September 2005.

Weiser, M. The Computer for the Twenty-First Century. *Scientific American*, pp. 94-10, September 1991 .

Weiser, M. Some Computer Science Problems in Ubiquitous Computing," *Communications of the ACM*, July 1993. (reprinted as "Ubiquitous Computing". Nikkei Electronics; December 6, 1993; pp. 137-143.)

Zappella., M. (Eds) Il metodo Portage. Guida pratica per l'educazione precoce. *Schede. Edizioni Omega*, Torino. 1990.