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# DESIGNING TANGIBLE TABLETOP INTERFACES FOR PATIENTS IN REHABILITATION

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**Abstract:** We investigated the potentials and acceptance of tangible tabletop (TT) interfaces in functional and neural rehabilitation. Our goal was to analyse whether TT systems are adequate for rehabilitation and its sub categories and whether these tools have the potential to create an added value for both patients and therapists. We further investigated conventional practices and rehabilitation tools that could be adequately adapted to TT interfaces. Based on theoretical work and on the results of two focus groups with therapists and a contextual inquiry we developed three concepts for TT tools. Finally we present the resulting paper and interactive prototypes.

**Keywords:** Tangible tabletop interfaces, rehabilitation, visual and cognitive impairments, fine motor skills, design process, focus groups.

## 1 Introduction

Conventional software for rehabilitation runs on common PC environments. The input and output facilities of these systems (keyboard, mouse and desktop screen) can represent a barrier for patients in rehabilitation. Tangible tabletop (TT) systems could possibly overcome these barriers as these systems‘ in- and output facilities are very close to the physical environment. Ishii and Ullmer (1997) first presented the concept of “tangible bits” and discussed the advantages of tangible media. Figure 1 shows the correlation between different domains (Pridmore et al., 2003). Tangible tabletops are primarily based on the concept of tangible bits and are therefore very close to the tangible bits project.

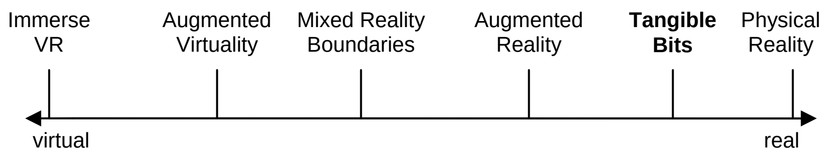


Figure 1 Relation between Virtual, Mixed and Tangible Media Environments

TT systems feature various physical interaction objects that are manipulated on a table’s surface. These objects may have different shapes and consist of different materials. Their position on the surface can be detected by different technical methods like pattern recognition or electro-magnetic object recognition (Patten et al., 2001; Bencina et al., 2005). The visual interface and feedback are projected onto the table by a projector positioned over or under the (see-through) surface. Characteristic examples of TT systems are SENSETABLE (Patton et al., 2002) and REACTABLE* (Jordà et al., 2005). Basic manipulation techniques and the relation between the virtual and physical world (interaction objects) are discussed in the BRICKS project (Fitzmaurice et al., 1995).

This work investigates whether TT interfaces have the potential to assist patients with visual impairments and a lack of fine-motor skills in rehabilitation by providing a human-computer interface that is close to physical reality (see Figure 1). Thus, we explored conventional training methods and facilities that could possibly be applied within TT environments. We also evaluated this technology in cooperation with therapeutic professionals to verify its acceptance and whether it could create an added value for daily therapeutic work (see Wann et al., 1997). Our work represents basic consideration about the applicability of TT systems for rehabilitation. It further contributes to the discussion about mixed reality environments for rehabilitation purposes (Pridmore et al., 2004).

## 2. Related Work

There are several projects that apply virtual (VR) and augmented reality (AR) technologies for rehabilitation. However, no project has been presented so far that is based on the concept of tangible tabletops. Therefore, we give a short overview of general TT systems that are relevant for our work in this section. Then we will discuss related VR and AR projects as well as studies about design processes that provide an insight into the field.

The TT systems SENSETABLE (Patton et al, 2002) and REACTABLE* (Jordà et al., 2005) that were originally designed for music performances helped us to understand the possibilities of different object manipulations and issues concerning object and pattern recognition. These projects deal with several cube-shaped objects with sizes ranging from 3 to 5 cm. COGNITIVE CUBES (Ehud et al., 2004) is a project that also applies the concept of tangible media for rehabilitation. The system uses tangible objects for the training of fine-motor skills and cognitive assessment. Patients have to rebuild a 3D shape that is visualized on a screen out of different physical cubes. On the basis of several user tests the authors believe that COGNITIVE CUBES could be adapted for a clinical environment. Edmans et al. (2004) discuss the design of a VR system that maps the preparation of a hot drink into a VR environment for the rehabilitation of stroke patients. The implementation of the system represents a complex challenge, since the patient's action as well as the system's reaction has to be considered. Furthermore, each task has to be analyzed in detail to rebuild it in the virtual world. Initial user tests and feasibility studies showed that the system itself is usable and could be adapted to rehabilitation sessions. In this study some patients had problems working with a touch screen. Crosbie et al. (2004) indicate that also head-mounted devices (HMD) could be inappropriate for the use in rehabilitation as different tests showed that the use of HMDs causes disorientation or nausea in some cases after the training sessions. Pridmore et al. (2004) suggested adapting VR environments with tangible interaction objects (e.g. using a real coffee cup with visual object recognition to locate its position). Hilton et al. (2000) also performed focus groups with therapists and concluded that professionals were very interested in the field of virtual environments. According to this study the most potential fields for VR applications comprise motor rehabilitation, navigation, visual field deficits and recognition of body parts.

## 3. Design Process

We decided to split the design process into three stages. First, we analyzed relevant medical and therapeutic literature (Presber and de Nève, 1990; Schweizer, 1999). The goal was to identify therapeutic practices and tools that were adaptable within TT environments. This was the basis for a first focus group with professionals at the Vienna General Hospital. It was attended by 5 therapists. Apart from information material the participants received a few days in advance, they were unfamiliar with the subject of tangible media. Therefore, we decided to have an open discussion instead of using a questionnaire. The goal of the focus group was to learn more about the therapists' opinion and their motivation to use such tools. According to Kankainen (2003) we call this basic attitude "motivation level needs". The purpose of the first focus group was to find out whether our considerations and findings in literature were adaptable to the practical therapeutic environment. In the meeting we presented basic materials and training tools that we considered appropriate for adaptation to a TT system. We also showed the participants two very basic paper prototypes with wooden blocks as interaction objects to demonstrate the concept of TT interfaces. The therapists discussed possible advantages and concerns about such systems.

The main result of the first focus group was that therapists supported the idea of using TTs for rehabilitation. The main fields of applying TTs are the rehabilitation of people with visual impairments and visual (and intellectual) perception problems (e.g. stroke patients). We also see some potential in the training of people who lack fine motor skills. In general therapists state that there may be advantages compared to common desktop systems, because a projection on a table surface would be more understandable to patients that cannot conceive the concept of a desktop screen. Furthermore, the interaction with mouse and keyboard is considered very complex for some patients. The TT approach could overcome these obstacles. One further outcome of the first focus group was that therapists appreciate the capability of TT systems to combine action and reaction of the system (feedback projected directly on the table's surface), which is important in the field of rehabilitation of cognitive impairments. In contrast, patients have problems correlate the movement of mouse with feedback on the screen (the moving curser). Thus, therapists were convinced that patients with perception problems would be able to use computers much earlier in the rehabilitation process when supported by a TT system. In general therapists stated that using new media applications could stimulate some patients and raise their motivation for their daily training. From the results gathered in the first meeting we derived the following design implication for the prototype design:

(1) Focus on existing therapy concepts and adopt/extend them for the TT environment

Subsequent to the first focus group we conducted a contextual inquiry at a rehabilitation session in the hospital. We expected to receive more information about the way therapists deal with patients, how they talk and act and about the contextual settings. As we did not want to disturb the training process we were only observers during the session. All occurring questions were discussed with the therapist after the session. The contextual inquiry revealed that a therapy session is a highly dynamic process between the therapist and the patient. The therapist provides exercises and gives feedback to the patient. A training session lasts from 30 minutes (standard) up to 60 minutes (exception). Trainings are held nearly every day. During a session different training materials are used and changed from time to time. The observed training session took place at a table (approx. 1.5x1m of size). Both, therapist and patients were seated at the table to work together.

Based on the results of the first focus group and the contextual inquiry we sketched three basic concepts of applications in form of paper prototypes (described later in this paper). These prototypes were evaluated in a **second focus group**. The goal of the second focus group was to identify the therapists' "action level needs" (see Kankainen, 2003). We aimed to reveal the therapists' expectations concerning the exercises and training materials itself. The second focus group was attended by 8 professional therapists. It was again held at the Vienna General Hospital. Four therapists already attended the first focus group; the others were not yet familiar with the issue. This caused a few initial problems since there were different levels of understanding of the basic concept of tangible media. However, this resulted in a very intense discussion that provided us with relevant information. Finally, we presented the paper prototypes and had a discussion about the concepts and their implementation.

In general we received positive feedback from the therapists who confirmed their willingness to work with such applications. For optimal results, it is necessary to provide various interaction objects that are different in size and weight (for training of fine motor skills). Furthermore, different levels of difficulty (fineness and number of the projected patterns) have to be available to assist the patients' progress. In the case of only one concept design (concept 3), therapists did not see a big advantage over the known and common exercise. This was due to fact that this concept is very close to an existing traditional version of an ergo therapeutic training material.

After explaining the concepts, we additionally asked five specific questions addressing different scopes of the prototypes.

- *Is the size of the interaction objects appropriate?* The size of the interaction objects proposed was appropriate. In the focus groups these were wooden bricks sized 5x5x5cm. Therapists said that interaction objects should be available in different sizes, weight and in different materials. For ergo therapeutic purposes shapes could be cylinders of different size and weight.
- *Is the size of the table surface appropriate, too big or too small (projected area)?* We presented the paper prototypes on an A3-sized surface (approx. 30x42cm). This was rated to be more or less appropriate, but the surface should not go below that size.
- *Do you think shadow caused by the projector mounted over the table could disturb the patient when grasping an object?* According to the therapists shadow is likely to disturb patients when

working with the TT system. Therefore there should be a solution that places the projector under a lucent surface. In contrast Wellner (1993) stated that users did not experience problems with shadows produced by the projector. This difference reveals the fact that for therapeutic purposes the interface has to be considered much more in detail to meet the special demands of the users.

- *Are recordings of the training sessions of any significance?* Therapists would appreciate basic recordings of date, time and trained exercises. However, they doubted that it is possible to representatively compare progressing exercise results of one patient as there are too many factors of influence that cannot be captured by the system (daily condition of the patient, etc.).
- *What kind of automatic feedback has to be provided by the application?* Therapists expressed the desire to choose between visual and audio feedback. Both should be adaptable individually or combined together. Audio feedback should be adjustable in volume. Visual feedback should be adjustable in brightness and in size of the projected space.

From the information gathered in the second focus group, we derived the design issues (2) to (5). Issues (3) and (5) are in agreement with implications made by Hilton et al. (2000) who held focus groups with therapists when designing a VR system for rehabilitation.

(2) Easy start/setup of hard- and software for use in therapy sessions
(3) Different types of interaction objects (size, weight, different materials)
(4) Different levels of difficulty and adjustable feedback for each exercise
(5) Automated basic therapy recordings are useful (patient, time, exercise, errors, etc)

After the second focus group we implemented the paper prototypes and conducted a first user evaluation with wizard of oz prototypes. This evaluation was held with 3 users that were not from the target group (non-rehabilitation patients). The feedback received was incorporated in the final concepts for the applications.

## 4. Resulting Prototype Concepts and (Hi-Fi) Prototypes.

The following concepts are based on the results of the two focus groups and the contextual inquiry. The user interface of the prototype was implemented with Macromedia Director. It uses the 4T framework in order to support easy translation into hi-fi prototypes, which could be used in controlled or longitudinal user studies. The 4T framework was developed at the Research Group for Industrial Software (INSO) at the Vienna University of Technology. The current version of the framework is based on the ARToolKit for visual pattern recognition. To describe the concepts in more detail we will discuss the main tasks of the concept, the challenges for the patients, and consequently split it into subtasks. We also mention the motivation for each concept and its relation to therapeutic materials and literature.

### *4.1 Concept 1: copy a projected pattern on the surface.*

This concept (Figures 2 and 3) is designed for training of people with a **lack of fine motor skills**. Patients have to follow patterns that are projected onto the table's surface and get visual feedback on the accuracy of their movements (interaction leaves coloured traces projected on the surface). The idea is based on therapists' statement that patients should copy written patterns with a (colour) pencil. This type of exercise is also found in literature (Goldenberg, 2002) where different pictures have to be copied by patients with visual or cognitive impairments (Figure 4). Therapists may choose from different interaction objects that patients have to use for task completion. Furthermore, therapists can decide between pre-stored patterns or sketching freehand patterns during the training session.

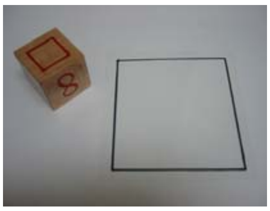
Figure 2


Figure 3

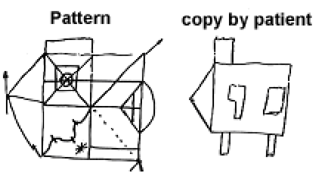

Figure 4

**Fig 2:** Low-fi prototype of concept 1 used in the second focus group
**Fig 3:** UI of wizard of oz prototype in Director
**Fig 4:** Sample sketches made by patients (Goldenberg, 2002)

Moreover, two-handed manipulation is possible. We consider the following subtasks for the prototyped application:

- Grasp one object from the working space
- Place object on or within the projected pattern
- Follow the pattern and copy it
- Receive and understand feedback (audio and/or visual feedback)

As there can be moved various objects on the surface simultaneously two handed manipulation is possible (one object in each hand). Thus all subtasks mentioned above can be applied to the two-handed scenario as well.

### *4.2 Concept 2: Compare patterns on physical objects and those projected on the surface*

**Concept 2** (Figures 5 and 6) may be used for rehabilitation work with people who have **visual and perception impairments**. Patients have to compare projected patterns with patterns printed on cubes. The design idea is comparable to different therapeutic materials that deal with different colours and patterns that patients have to compare (Figure 7). In this concept patients receive feedback that tells them whether the patterns concur or not (the position and angle of cubes being examined). Feedback (visual and/or audio) can be adjusted and is given on placing a cube within a projected pattern. Visual feedback is projected directly on the interaction object. The concept's subtasks are:

- Grasp and move one or more objects on the surface
- Align patterns printed on objects with those projected onto the table
- Place object within the projection and adjust the right angle
- Receive and understand feedback given by application (audio and/or visual feedback)

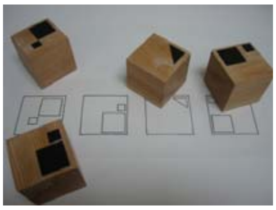
Figure 5


Figure 6


Figure 7

**Fig 5:** Low-fi prototype of concept 2 used in the second focus group
**Fig 6:** UI of wizard of oz prototype in Director
**Fig 7:** Ergo therapeutic material used by therapists.

### *4.3 Concept 3: compose a pattern according to the projection on the surface*

This concept is similar to concept 2. Patients can train their spatial perception by placing cubes within projected patterns. This concept is close to an exercise described by Schweizer (1999) where patients have to rebuild figures in the 2D space. These exercises are sketched for people suffering from **visual impairments and perception problems**. Patients have to compare projections with lines printed on the interaction cubes and rebuild a certain pattern projected onto the table. We identify the following subtasks for the application prototype:

- Grasp and move one or more objects on the surface
- Align lines printed on the objects with those projected onto the table
- Place object within the projection and adjust the right angle
- Receive and understand feedback given by application (audio and/or visual Feedback)


Figure 8

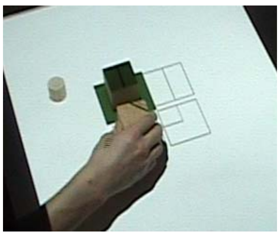
Figure 9

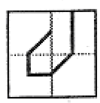
Figure 10

**Fig 8:** Low-fi prototype of concept 3 used in the second focus group
**Fig 9:** UI of wizard of oz prototype in Director
**Fig 10:** Example in rehabilitation literature given by Schweizer (1999)

The three concepts were **evaluated with three test users** that were no rehabilitation patients. The aim of this evaluation was to identify principle design errors and to receive initial feedback of nonprofessionals about the concepts. The evaluation showed that users generally understood the concepts. Since they were not familiar with TT systems, they had a few problems in the beginning to understand how the applications worked and how they had to use the interaction objects. According to the results from this evaluation we had to make slight changes to the interface. A major problem was that green and red was used throughout the interface, not only for the purpose of giving feedback. We consequently replaced these colours.

## 5. Conclusions and Future Work

Based on the concept of tangible media and TT systems we developed three concepts for rehabilitation exercises for the fields of visual impairments, visual (and intellectual) perception problems and training of fine motor skills. We conducted three design stages, which comprised two focus groups with therapists and one contextual inquiry. Further we defined five design implications for TT systems in rehabilitation. The concepts proved to be accepted by the therapists. From the considerations so far we believe that TT systems are a valuable assistive technology in rehabilitation. We plan to implement the concepts in a currently developed TT framework. In near future we will confront therapists and patients with these interactive prototypes to evaluate the concepts within the target group. From these sessions we expect to gain more information about the concepts and technical constraints. Based on this evaluation and on the results collected so far we plan to define guidelines for TT systems in the field of rehabilitation.

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