Touch and Tangibles – Interacting with fun.tast.tisch. Results of a Study with Non-Target-Group Users

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ABSTRACT

fun.tast.tisch. is an interactive tabletop system used in neuro-rehabilitation. It consists of several exercises to be interacted with by therapists and patients collaboratively. The user interface combines different interaction paradigms and tangible objects to facilitate therapeutic concepts. The acceptance of the system and its user interface relies on therapeutic aspects but also on straightforward interaction, usability and a positive user experience. A study with non-target-group users was conducted, first, because earlier studies revealed that the target groups are not fully impartial regarding perceived usability/user experience. Second, interaction combining a touch-based interface with tangible elements and system feedback on different sensory channels involves usability/UX challenges that should be investigated in a non-critical situation. This paper describes selected fun.tast.tisch. modules, especially those involving tangible objects and summarizes the results of a related study.

Categories and Subject Descriptors

H.5.2 [**Input devices and strategies**]: User Interfaces; H.5.2 [**Interaction styles**]: User Interfaces; H.5.2 [**User-centered design**]: User Interfaces

General Terms

Human Factors

Keywords

Tabletops, Tangible Objects, Rehabilitation, Evaluation

1. INTRODUCTION

The tabletop system fun.tast.tisch. was developed as a supplement to conventional therapy in neuro-rehabilitation [3, 4] and consists of several modules (14 at the moment) that train different skills (e.g., attention or motor skills). Samsung SUR40 with Microsoft PixelSense was chosen as tabletop technology for two reasons: physical objects can be included in the interaction and it can be used by several users concurrently due to the high number of touches recognized. Both are beneficial for us, as tangible objects facilitate the integration of haptic experience in the therapy process (e.g., to train fine motor skills), and conventional therapy sessions involve at least two people. fun.tast.tisch. is a joint endeavour of an interdisciplinary team consisting of occupational therapists, software developers, and interaction, graphic and object designers. The target group comprises patients but also therapists who are responsible for a main part of the interaction with the system (e.g., they have to navigate through the User Interface (UI), select the modules fitting the patients' needs, and configure them accordingly). Patients then have to perform the tasks provided by the respective module and their therapist. Both are intended to work with tangible interaction elements in several modules.

Most patients working with fun.tast.tisch. suffered acquired brain injury (often caused by stroke or accident) and incurred cognitive and/or motor impairment. Conventional therapy aims at training, e.g., attention, memory, visuo-spatial abilities or motor skills; thus related therapeutic concepts are the basis for the different fun.tast.tisch. modules as well. The development process is accompanied by evaluation along different dimensions. First, there have been two longer-term studies in a rehabilitation hospital (see [4, 2]) that however did not include some of the modules presented in this paper by then (e.g., some of the ones involving tangible elements). Therapists have been in the focus of usability/User Experience (UX) parts of these studies, although the therapists also were asked to assess the applicability for the individual patient's needs (it was not possible to do an exhaustive evaluation with the patients themselves for ethical reasons). Second, there have been numerable evaluation sessions with individual patients accompanied by the therapists of the fun.tast.tisch. team. Third, a randomized controlled trial was conducted during the second longer-term study in the hospital in order to assess the training's effect.

The study summarized in this paper had different objectives. First, we wanted to test new tangible elements in a non-clinical context. Second, we felt during earlier studies that therapists and patients naturally focus on therapeutic aspects (we observed that their perception of usability and UX tends to be biased by issues related to the underlying therapeutic concepts). Thus, we used a setting with a comparatively high number of non-target-group participants and tested 7 modules (3 had not been tested in a larger-scale study before, 4 involved different tangible objects).

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2. RELATED WORK

This section provides an overview on related approaches in the area of virtual rehabilitation, focusing on the integration of tangible elements.

De la Guía et al. [6] present the rehabilitation system TraInAb, based on a tangible UI for cognitive therapy (e.g., to train memory skills). TraInAb comprises a set of interactive games close to everyday activities. It is based on a mobile device including an NFC reader and involves physical objects that carry NFC tags to be recognized.

Sharlin et al. [8], [9] focus on spatial tangible UIs and discuss the Cognitive Cubes tool for assessment of 3D spatial cognitive ability. Cognitive Cubes uses a Lego-like tangible UI for the description of a 3D shape (users are shown a shape they have to rebuild). The visuo-constructive aspect is also considered by fun.tast.tisch. (see the Tangram module [4]).

Rand et al. [7] present an approach to virtual rehabilitation using Sony PlayStation II EyeToy. Their main target group are elderly people with disabilities. They describe three pilot studies conducted with different participants and found out that although healthy elderly participants enjoyed using the EyeToy, there are limitations of the technology when being used by acute stroke patients (e.g., patients who sufferend from severe weakness of one body side were frustrated because they could not interact well with a system that could not adapt to these limitations).

Wilson et al. [11] present the "Elements" system for rehabilitation of upper limb function in traumatic brain injury patients. They evaluated patients' performance but also assessed user involvement and satisfaction. The system comprises an LCD display placed horizontally, a camera tracking system and tangible objects (threedimensional objects in shape of a cylinder, pentagon, triangle, rectangle). The objects can e.g. be used to be placed on a specified target area which will activate an animation and sound.

Alamri et al. [1] describe haptic rehabilitation exercises for poststroke patients. Their framework is targeted towards diagnosis and rehabilitation of patients with hand impairments. The framework comprises haptic exercises and involves a sensory and a simulation system and a data repository. CyberGrasp [5] (the haptic device used) involves a glove with sensors to read the coordinates of all fingers to be able to reconstruct a realistic avatar of the hand in a virtual environment, and provides force feedback to the fingers.

3. THE FUN.TAST.TISCH. UI

fun.tast.tisch. is an interactive tabletop system, thus a major way to interact with the UI is via touch. Our tabletop technology uses an optical display, thus it is also possible to recognize physical objects placed on the screen. fun.tast.tisch. involves several tangible elements as interaction with physical objects is well suitable for e.g., training of motor or spatial skills. fun.tast.tisch. does not involve further interaction with conventional means (such as keyboard or mouse). This section describes briefly the different interaction modalities.

3.1 Touch-Based Interaction

The navigation through the main portal, including users' login and registration, and the selection and initial configuration of the modules, is done via touch. As entering textual information is a bit inconvenient via touch, we aimed at reducing the amount of necessary textual input to the minimum possible degree (the registration process is the only part of the system that requires it). The system allows for "sessions" that therapists and patients are assigned to. The session information is needed, as the system also provides a statistics feature. Therapists' and patients' registration can be done using a virtual keyboard, login is however intended to be implemented using tagged cards to be placed on the display. It is also possible to work in an anonymous mode that does not require registration (this however means that sessions later cannot be associated with the users). For the therapist's tasks, the main part of the interaction is via simple touch-based selection. For patients (who usually don't navigate through the settings dialogues but solve exercises), there are two more ways of interacting via touch, a two-handed touch, where two different target spots have to be touched at the same time (this is actually relevant for therapists also), and a delayed touch that has to be held for a longer time to select an object on the screen. The latter was introduced for two main reasons: first, the exercises using it require the user to purposefully select objects (e.g., if multiple objects are available and the user has to choose the correct one) and we aimed at preventing a trial and error approach where users just wipe over the display or touch randomly. Second, we wanted to avoid unintended selections with arms or elbows. A delayed touch starts an animation that is finished when the required duration is reached (see Figure 1 – the green circle around the touch position indicates that the delayed touch has been started).

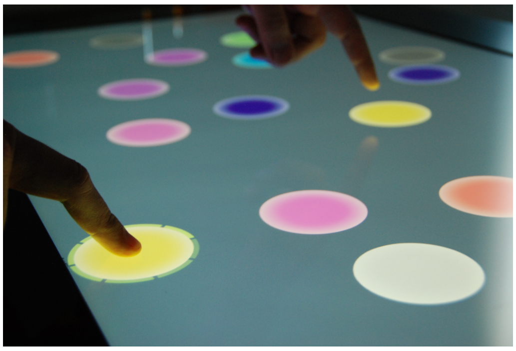

Figure 1: Interaction via delayed touch.

3.2 Interaction Using Tangible Objects

Several fun.tast.tisch. exercises, especially those training motor and spatial skills, benefit from the integration of tangible objects (see Section 4 for details). Generally, our UI involves two different kinds of tangible elements: first, objects that are recognized via tags, and second, non-tagged objects that are either recognized by the system based on their shape or do not require to be recognized. Tagging objects is the simplest way to have them recognized, which is why we chose this option in all cases where it was possible. However, some aspects of our interaction design did not allow for the objects to be tagged, e.g., because some objects need to be flipped over by the patients and be used from both sides. We decided not to tag both sides of (flat) objects for aesthetic reasons, and because the semi-transparency of these objects should be exploited for a certain kind of visual feedback (see Figure 2 [3]). This kind of feedback "highlights" the physical objct by showing a colored area directly under it (green color was used to mark a task as correct).

Most physical objects were designed for one or more specific

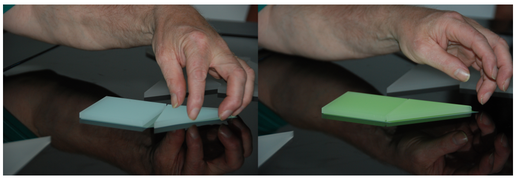

Figure 2: Visual feedback exploiting the characteristics (semi-transparency) of the object material in the Tangram module (see [4]).

modules, one can however be used throughout the whole module set to change the level of difficulty on real-time, i.e., during the patient's interaction. The object has the shape of a cylinder (see a picture in [4]) and is used by therapists only. The purpose behind this kind of interaction was to be able to discreetly adapt the difficulty, without discouraging patients and without having to interrupt an exercise.

The material of all objects was chosen carefully based on different considerations. Some physical interaction elements needed to be semi-transparent, others needed to be fully transparent (e.g., in case the system should not recognize them). The modules that allow for a multi-patient setting needed objects of different patients to be distinguishable, which was solved by different colors. Further, all objects needed to be easily clean- and disinfectable, well graspable (these are domain-specific requirements) and needed to be solid enough not to break when dropped. After tests with different kinds of materials, we arrived at i) objects made of acrylic glass, individually designed for fun.tast.tisch., and ii) 3D printed ones. Figure 3 shows the different kinds of physical objects currently used within fun.tast.tisch.

Figure 3: The different kinds of objects that are part of the fun.tast.tisch. user interface.

4. SELECTED MODULES

This section presents the 7 modules that have been tested regarding usability/UX in the study with non-target-group users. One module (Tangram) has been exhaustively evaluated earlier [4] and was not included in the study.

4.1 Shopping

This module (see [4] for an early version) aims at training memory functions. It is not the primary goal to remember as much as possible, but to realistically assess one's own memory ability. A user has to decide how many goods to buy before a digital shopping list displays the goods to be memorized and later picked from a "shop" containing up to 25 goods. The level of difficulty can be individually configured by setting the number of goods to be shown in the shop, activating different kinds of distractors or introducing a longer memory span. The main interaction paradigm used here is based on physical objects. Users have to pick the goods from the shop by placing acrylic glass tagged "shopping coins". The number of coins to be used matches the number of goods to be memorized (3 to 7). A coin placed on a good will make it appear in the user's digital shopping cart, removing the coin will remove the good from the cart. Touch-based selection would not have been an option because the module offers a setting where up to 3 users pick goods from a shared shop (see Figure 4). Every user receives individual goods and an own shopping cart; it would not be possible to associate a touch with a specific user. The coins can be distinguished by the users based on their color. The module further involves a tangible shopping list for every patient the shape of which is inspired by the one of a paper-based notepad. The list is used to re-show the goods in case they have been forgotten. A tag under the lower part of the object is used to let the system recognize it (the major part of the object is transparent). When placed on the display, the digital shopping list is re-shown exactly under the transparent part of the object. The module provides acoustic and visual feedback after the task has been solved (i.e., after all goods have been correctly selected).

Figure 4: Interaction with the Shopping module in the multi-user setting.

4.2 Where's the Food?

Where's the Food? (see a picture in [2]) trains attention abilities. The user is shown a line transporting food (as common in a running sushi restaurant). The line transports empty plates and plates with food on them. Every time the user notices food, a digital bell has to be rung. The task is solved after the user has "colleted" all food for a complete menu. The therapist can decide whether alertness or selective attention should be trained. In the alertness mode, the line offers empty plates and plates with food only. In the selective attention mode, the user has to distinguish between food and non-food objects on plates. Different kinds of distractors can be activated: acoustic (e.g., restaurant noise), visual (e.g., random objects on the line), and animated (e.g., a digital fly moving around the table) ones. The user receives acoustic and animated feedback if a plate with food is missed. After all food has been collected, the user receives a picture of the complete menu and acoustic feedback.

Figure 5: The module "Window Washing" with physical cleaning element fixed to the user's hand.

4.3 Window Washing

Window Washing (see Figure 5) trains motor skills. The table shows a picture covered with digital dirt that has to be "wiped free" by the user. The therapist can choose between three picture sizes (depending on the user's reachable screen areas). The patient uses a physical object (or alternatively a common towel) that can be fixed with his/her hand to wipe away the dirt (as shown in Figure 5). The object is transparent because it should not be recognized by the system (the dirt is removed based on the shape of the user's hand).

4.4 Match the Pairs

This module (see Figure 1) displays to the user a number of filled colored circles, two of each color. This module uses two-handed and delayed touch (see Section 3.1). The user has to find the two circles belonging together and touch them (one with each hand) at the same time, which will make them disappear. The process has to be repeated until no circles remain. The therapist can set the number of pairs that should be displayed and choose whether to use the colored circles or pictograms. If the user cannot use both hands, the module can be configured to be operated with one hand only (via delayed touch, the two items have to be touched one after the other within a certain time span).

4.5 Spot the Difference

Spot the Difference [2] is used to train cognitive skills and presents to the user two photorealistic pictures that differ from each other in a fixed number of details. The user must find these differences and mark them in the picture by delayed touch. The therapist can set the level of complexity and decide which of the two pictures should be the original and which should be the one containing the "mistakes" (depending, e.g., on the impaired side of the user).

4.6 Spatial Cognition

This module (see Figure 6) trains spatial cognition skills. The therapist places a set of physical objects on the display, the table then generates different up to 4 three-dimensional models that show the objects from different perspectives (the patient has to choose the correct one). The therapist can decide how many perspectives should be generated and which one should be asked from the user. The module can be used with two different sets of objects: simple (e.g., a pyramid, made of acrylic glass) and complex (e.g., a house, 3D-printed) ones. All objects are tagged to be recognized by the system. We consider this (and the following) module a successful fusion of physical elements and a digital world.

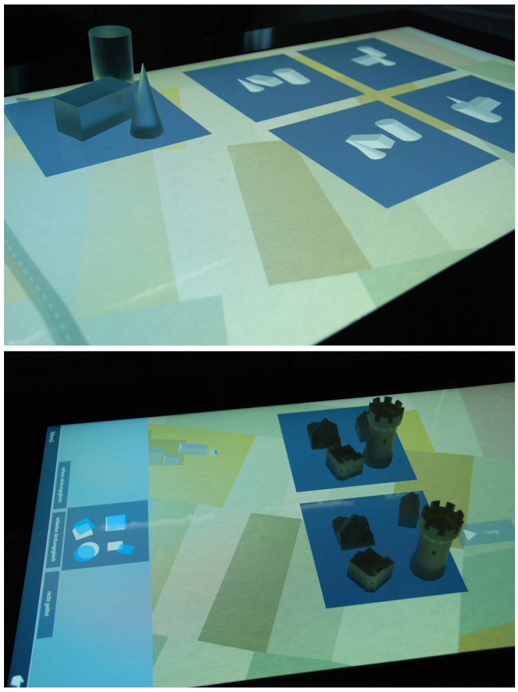

Figure 6: The modules Spatial Cognition (simple objects) and Spatial Construction (complex objects).

4.7 Spatial Construction

This module (see Figure 6) trains spatial construction skills. The therapist places a set of physical objects on a certain area of the display, the patient then has to rebuild the setting with a second set of identical objects. The therapist receives an overlay picture generated by the system showing the footprints of both sets of objects and can decide how well the patient has solved the task. The module uses the same objects as the Spatial Cognition module, thus the therapist can choose between simple and complex ones.

5. STUDY

This section describes the general aims and setup of the study, the applied method and participants.

5.1 Aims and Participants

It was our aim to evaluate selected modules along general usability and UX related dimensions, intentedly not specific to the domain of neuro-rehabilitation. 85 probands participated (39 male, 44 female, 2 unknown). They were between 10 and 54 years old ($\overline{x} = 21.87$). Most of them showed high affinity towards technology, 89% stated to own a smart phone and 88% to be experienced with touch devices and use them on a daily basis (11 had little or no experience). They participated voluntarily during a university open house.

5.2 Method

We followed a task-based user test approach. The tasks to be done by the participants aimed at covering all possible user interactions, including use of tangible objects. Every participant did one or more tasks and answered a web-based questionnaire afterwards. The questionnaire contained about 230 questions in total, however, the participants received a personalized set of questions (in most cases between 30 and 50) based on the modules they tested. As fun.tast.tisch. is designed for therapy settings, we split up the tasks into subtasks for therapists and for patients. Each task required a setting with one participant to take over the therapist's role and at least one "patient". We aimed at getting an overview on the perceived usability and UX of the whole UI, but also specific to each of the evaluated modules. In total, we received results for 166 role/module combinations: 16 "therapists" and 25 "patients" for the Shopping module, 7 "therapists" and 7 "patients" for Where's the Food?, 9 "therapists" and 13 "patients" for Window Washing, 9 "therapists" and 11 "patients" for Match the Pairs, 6 "therapists" and 9 "patients" for Spot the Difference, 14 "therapists" and 18 "patients" for Spatial Cognition, and 9 "therapists" and 12 "patients" for Spatial Construction. Based on the classification of usability-related criteria by [10], the following criteria were used for the evaluation of usability: effectiveness, safety, utility, and learnability. Concerning UX we relied on the following attributes that can be used to describe a system [10]: "satisfying", "enjoyable", "fun", "entertaining", "helpful", "motivating", "aesthetically pleasing", "supportive of creativity", and "emotionally fulfilling".

6. FINDINGS

This section provides a concise overview on the study's results, mainly related to interaction.

6.1 Usability

The **effectiveness** of the system was partly investigated by asking whether the cooperation between (fictitious) therapist and patient(s) worked well, which most participants unanimously affirmed. For therapists, other questions dealt with control of the workflow, e.g., related to starting/pausing modules or changing settings (e.g., the level of difficulty). Most cases where problems were reported were related to insufficient task descriptions (not relevant for application in real settings) and minor UI issues (like e.g., a misleading button label). Patients' questions were related to the exercises themsevles, e.g., whether selecting or moving elements worked well. The delayed touch interaction that turned out to be critical in earlier tests worked and was understood well. Nevertheless, this kind of interaction must be explained beforehand as it is still not fully intuitive, although we tried to design the animation to indicate that the touch needs to be held for a longer time.We asked patients if the different perspectives in Spatial Cognition were clearly recognizable, i.e., differ sufficiently (17 of 25 found this to be "very good" or "good'). Regarding the handling of the physical objects we found out that participants liked them and understood how they should be used well. At the Shopping module, all but one of 25 patients stated to have known how to use the coins. 23 of 25 found the shape of the coins and properties of the material "very good" or "good". The coins were e.g., described as follows: "perfect size", "easy to handle", "easy to grasp", "funny", "fits well in the hand", "compact and handy". The only negative description was "a bit too small". 8 of 14 found the shape and properties of the objects in Spatial Cognition "very good", 4 "good". Regarding Spatial Construction, all patients and all but one therapists declared that they knew how they had to place objects on the table and all but one liked the shape and material.

In order to identify potential **safety** issues, participants e.g., were asked whether anything unexpected occurred during the training. The results show a higher number of unexpected events mainly in the Shopping module. However, the main situation participants described as "unexpected" was the "distraction" game that started between memorizing goods and picking them from the shop in order to increase the memory span. Although this behavior was of course unexpected for first time users, it is desired. In summary, we identified minor safety issues most of which originate in technical issues that partly have been solved meanwhile.

The **utility** criterion is concerned with the individual user (and his/her ability to use a system in the ways he/she wants to). Accordingly, we asked utility questions in cases where a task could be performed in more than one way. E.g., at the Shopping module, users might have forgotten goods they should have memorized. From a utility perspective, it is of interest if the system provides sufficient means to help the user achieve the task. 5 of 25 patients made use of the physical shopping list and all of them stated that they understood how it could be used. However, 2 participants initially placed the physical list on the table upside-down. Another utility example is the therapist's menu: all exercises can be ended by using this menu that is not intended to be operated by patients. We also had to make sure this menu is not activated unintendedly (as it is located near the therapist's sitting position). Thus, users have to perform a two-handed touch (on two corners of the table) to activate it. 7 of 9 therapists knew how to use the menu at the Window Washing module, 8 of 9 at Match the Pairs, 11 of 14 at Spatial Cognition, and 7 of 9 at Spatial Construction.

Regarding **learnability**, we aimed at finding out how fast the participants understood how the exercises worked. With only few exceptions, all therapists and patients stated to have understood how the exercise worked "very fast (was self-explanatory)" or "fast" for all modules. No participant selected "very slow (was confusing)" or "slow". Further, we asked how well participants got along with the overall system (navigation, etc.) to find out how fast they could work with it after a relatively short period of time. On a scale from "very well" (1) to "very badly" (5) , 35 patients rated 1, 20 chose 2, 4 chose 3, 1 chose 4 and 0 chose 5. 26 therapists rated 1, 17 chose 2, 3 chose 3, 0 chose 4 or 5.

Summarizing usability-related findings, no critical usability threats but a number of smaller issues were identified. The interaction with tangible objects was perceived exceptionally positive although most required a short introduction on how they should be used to interact with the system. After the introduction, there were no complaints about handling the objects or understanding how they should be used.

6.2 User Experience

Regarding UX, participants had to describe how well four of the aforementioned UX adjectives described the interaction with the system at the module level. They were asked whether they found the module to be "fun", "entertaining", "motivating" and/or "aesthetically pleasing" (each on a 5-

item Likert-scale). We used this reduced set of adjectives because not all of the other adjectives would have matched all kinds of exercises. Another aspect evaluated at the module level was the perception of feedback. Patients were asked whether they noticed feedback and if so, if they understood it and to what extent they perceived it as "motivating". The results revealed that in all modules the system's feedback was perceived as (very) motivating by the majority of the participants (16 of 19, 6 of 7, 9 of 9, 5 of 6, 6 of 7, 12 of 14 and 10 of 10). Additionally, both groups were asked how they perceived the overall interaction with fun.tast.tisch., using a larger set of adjectives. As shown in Figure 7, the attribute "fun" was most often (by 63) fully agreed with (additionally, no participant selected "disagree" or "fully disagree"). Given the study was conducted with non-target-group users, this is a highly desirable outcome. Other studies have already shown that for the actual target group, mainly patients, the system is perceived as motivating and helpful. Non-target-group users are naturally less in need of motivation for therapeutic exercises and might thus have rated attributes like "satisfying", "motivating" or "helpful" less important.

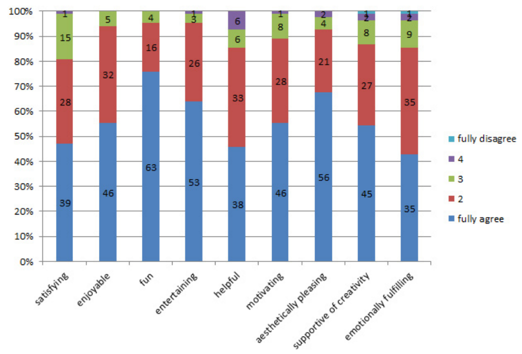

Figure 7: All adjectives to describe the overall interaction with fun.tast.tisch. as rated by the participants (fully agree (1) to fully disagree (5)).

7. DISCUSSION AND FUTURE WORK

We have described the different interaction paradigms of fun.tast.tisch. and selected modules and presented the results of a study conducted to evaluate the usability and UX with non-target-group users. Even though we intentionally excluded the actual target groups from this study, they play the most important role in the overall evaluation of fun.tast.tisch. The system has been repeatedly tested with real users, e.g., in longer-term evaluations at a rehabilitation hospital [4]. As summarized in Section 6, only minor usability issues were identified and the UX was predominantly described as positive. The physical objects were accepted exceptionally well, although most kinds of non-obvious interaction (i.e., interaction most people are not used to, according to their experience with other touch-based devices) required a short introduction before it was understood. As fun.tast.tisch. is used in a domain where detailed instructions are provided for therapists before they actually use the system (and patients are instructed by their therapist), this does not pose a major problem. Until late 2014, additional modules (partly involving new tangibles) will be added.

8. ACKNOWLEDGMENTS

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