Towards a Smart System for Rehabilitation:  
TANGO-H Recommender System

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The main objective of this work was to build an intelligent system for user rehabilitation. The system comprehends a platform with an exercise player and a designer tool. The intelligent platform analyzes the user interactions with it at every time along with the user record evolution to recommend new activities to the user. The main contributions of this work are, firstly, the definition of a recommender system based on different difficulty levels and user skills. The recommender system therefore has the function of providing the user a personalized game mode based on his own records and preferences. Secondly, a gamified system has been developed in the platform to increase the motivation of users and to prevent them from abandoning. Lastly, a twofold validation of the built system has been performed, with a group of experts in the first place and in a real intervention with children afterwards.

Keywords: Recommender systems, Exergames, Rehabilitation, Gamification, Serious games

1. Introduction

Nowadays, exergames are been used by therapists as a tool for rehabilitation purposes [1,2,3]. An increasing number of studies have introduced exergames in rehabilitation with the goal of motivating, engaging and increasing the adherence of patients to their treatment [2]. These researches confirm the motivational benefits to use exergames in rehabilitation, independent of the age of users or their illness [4,5,6]. Some researchers have been using commercial exergames platforms such as Wii or Xbox games for physical rehabilitation, but they can not fulfill the complete requirements of the rehabilitation therapy. It is important that the game not only allows the assignation of the exercises to users, but also give recommendations about how the exercise has to be performed. Another problem is that the therapist needs to design his own exercises for each particular rehabilitation and create a plan adapted to the particular characteristics of each patient or group of users with similar needs. Exergames also can be used to work the psychomotor competencies. These competencies includes fundamental motor skills (coordination, balance, posture, body schema and image), perceptual motor skills (spatial and temporal skills and rhythm), and cognitive skills (reasoning and memory) [7].

In this sense, we created a platform named TANGO:H (Tangible Goals: Health) that allows the creation of active games for rehabilitation of hospitalized children [8]. The main motivation for the creation of this platform is to meet the social, physical and cognitive needs of hospitalized children. In the Canary Islands around 1368 children has been hospitalized last
year in the centers that have the seven hospital classrooms distributed among the islands. The collaboration and discussion with doctors and specialists on the needs of these patients established the need to develop playful tools, based on technology, in the form of activities that improve and strengthen the physical and motor abilities of patients. Accordingly, a tool can be implemented to take advantage of the technology so that hospitalized children can continue working on their physical, cognitive and social status during the time they are in the hospital, and making it as entertaining as possible. As a consequence, the evaluation of the playability, emotional states and social interactions are very important in our work.

Therefore, the design and development of TANGO:H has the following main objectives:

- To be an accessible and configurable open platform for the creation, personalization and adaptation of exercises and activities based on the characteristics of the users.
- To be a social platform for games and rehabilitation that continues to use gamification to motivate users.

In the following sections, we will describe the TANGO:H platform, how we have applied gamification in the application, and the incorporation of a recommendation system that provides the user with a new form of game based on his user profile and its interaction with the platform, which the main objectives of this work. The validation of the obtained platform is included afterwards.

2. Related Work

Gamification and Serious Games in rehabilitation is a research area at present time. One of the principal problems of the rehabilitation is that the therapy sessions can be boring. Those sessions normally consist in repeating the same exercises again and again. Games can contribute to improve motivation, make patients work harder, etc. [9,10]. There are several papers of related work which contains classifications of game characteristics for rehabilitation. In 2008, Flores et al proposed a classification for elderly rehabilitation [11] and in 2009, Burke et al. proposed a classification of upper limb stroke rehabilitation techniques, using games development following the design principles of challenges [12]. But most applications are prototypes, designed for a single user and used at Hospitals [9]. Nevertheless, we consider that a multiplayer system allows interaction and increases the motivation of users, permitting patients to collaborate and compete, and favoring recovery. Accordingly, the TANGO-H application allows different game modes: single-player and multiplayer, collaborative and competitive modes.

In recent years, games and Virtual Reality (VR) have been developed as intervention tools in rehabilitation [13,14,15,3]. In the literature we can find studies that show that VR can increase motivation whilst used in rehabilitation and also allows realistically situations that otherwise would be difficult for patients [16]. Some other conducted studies show that the use of the Wii and Kinect platforms are useful in rehabilitation [17,18,19]. Currently there are evidences about applications using Kinect in rehabilitation, due to the fact that developers can design games and applications for the Kinect sensor, as its software development kit (SDK) is available. Several publications have analyzed the use of Kinect for the development rehabilitation games [20,17,21]. Consequently, the number of gamified systems and serious games for rehabilitation [22,23,24,25,1] has increased. There are examples in the physical rehabilitation of upper and lower limbs [10,26,21], gamification in Stroke Rehabilitation [27,28], for people with motor disabilities [17,29], etc.
We can also find works on recommender systems in rehabilitation. In 2015, Mahmoud et al. presented a recommender system for rehabilitation of people with disabilities, specifically for spinal cord injuries [30]. Catalá et al. 2014, developed EDIT, a recommender system of games for disabled and elderly people [31]. EDIT collects information from patients and shows them a list of rehabilitation games appropriate to their disability.

3. Platform TANGO:H

Tango: H is a platform of accessible educational games based on Kinect, where the user's interaction with the system is done through the human body and the recognition of gestures, without the need of have physical contact with traditional control systems. Tango-H is an open and highly configurable platform that allows the creation, personalization and adaptation of exercises and activities according to the characteristics of each user or group of users [8]. The principles on which the creation of this platform has been based boil down to the fact that one of the main characteristics to be achieved through a game or a platform of this type is to ensure that the activities carried out through them are pleasant, not repetitive. This is, to provide the user with an experience that from the first moment creates in him the need to move forward and continue experimenting with the platform. For this reason, one of the main objectives of this work is to incorporate an exercise recommender system that provides the user with a new exercise game, or activity, based on his user profile and interaction record with the platform. In addition to this mode, activities oriented to different types of players are provided. Additionally, the implementation of a game level control system provides a greater adaptation and personalization of the exercises. For example, activities proposed to new players are basic, allowing them to adapt to the system while they learn. Activities proposed to more experienced players are more difficulty, avoiding to become repetitive and supposing a new achievement to the user. This perspective also helps guiding the activities during patient rehabilitation. That is, the game will start with simple activities for the patient, but with effort and the improvement of his user profile, the activities will have a higher level of difficulty, which will require extra effort in more areas of his body.

The description of the TANGO:H platform and the different systems implemented to provide intelligence to the platform can be found below.

The Tango platform: H is divided in two parts:

- TANGO:H, which focuses on the users and the interaction with them. Its purpose is the execution of previously defined exercises/games that will be selected by the users as well as the game mode in which will be carried out.

- TANGO:H Designer, which focuses on the doctors or specialists in order to allow them design the exercises, establishing the steps and phases that the user must solve to achieve a satisfactory execution of the exercise. In addition, the designer also allows to specify the objectives of the exercise, so that the game will be evaluated according to the achieved ones.

At the exercise creation time the designer defines the type of exercise. Those types that can be: physical, cognitive or free. Exercises of the "physical" type base their operation on getting a stimulation of the user's joints through the use of figures, called objectives. Those figures are distributed on the screen by the designer, showing with colors the objectives and body parts that the user has to use at each moment to achieve a satisfactory completion of the exercise. This way, the designer is able to establish a type of exercise aimed to users with reduced mobility or physical problems. The "cognitive" exercises base their functioning on the
cognitive development of the user. These exercises aim to improve the perception, memory, learning and reasoning abilities of the users by using different pairing, ordering and classification tasks. Finally, the "free" exercises are configured in such a way that they do not follow any kind of pattern.

4. Gamification

The gamification is based on applying the mechanics of games in other environments, in order to enhance motivation, concentration, effort, etc. [32]. Games have addictive aspects, which can be applied to other environments to attract users so that, they can perform certain actions, in order to acquire habits and achieve goals [33].

The three basic principles on which gamification is based, can be defined as [34]:

- Mechanics that allow the user to be engaged in activities that are intended in a funny way. For example, points, levels, prizes, classifications, challenges or missions.
- Dynamics that establish the personal motivations of each user when participating in the gamified activity. For example rewards, achievements and competitive or collaborative systems.
- Components: These are the specific implementations of the game dynamics and mechanics. They may be the use of avatars, game scores, medals, badges and the player status.

The different systems implemented to provide the gamification to the TANGO-H platform are the following [35,36].

4.1. Game modes

There are several game modes which can classified based on the number of players that perform the exercise: singleplayer and multiplayer.

1. Singleplayer: A single player will carry out the activity.
2. Multiplayer: The game is carried out by several players and the platform will provide several game modes to improve the experience. The different game modes that are allowed are: sequential, collaborative and competitive.
   - Sequential: Two players play alternatively performing the same exercise of equal complexity one after the other.
   - Collaborative: Two players participate in the same exercise simultaneously, helping each other to overcome it.
   - Competitive: Two players face the same exercise of equal complexity simultaneously, with the aim of finishing the exercise before the opponent.

4.2. Gaming elements

Different gaming elements have been included in TANGO:H such as: points, leaderboards, status, feedbacks, achievements, levels, avatar customization, etc. Table 1 show in more detail the gaming elements included in TANGO-H [35].
Table 1. Gaming elements

<table>
<thead>
<tr>
<th>Elements</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Points</td>
<td>Points are a numerical valuation of the performance of the user, similarly as we get with sport scores, grades, etc. Points are assigned on each activity as a function of the number of goals reached, and the time needed to be finished. Each game mode assigns differently the points to users: In single-player mode or sequential multiplayer mode each user receives a score. In a competitive multiplayer mode two scores are assigned, one for each user, while in the collaborative multiplayer mode a single score is assigned for both users.</td>
</tr>
<tr>
<td>Leader boards</td>
<td>A leader board is just an order list of the users based on some scores. The lists might allow comparing users globally or locally based on some selection criteria. The leader boards exploit the social emotions, such as feelings of ‘fame’ and status, while allowing the comparison between users and enhancing competition among them. In TANGO-H there are leaderboards of single players and groups.</td>
</tr>
<tr>
<td>Status</td>
<td>The status is a categorization of players based on their scores. The motivation is based on the aim of users to reach a high status.</td>
</tr>
<tr>
<td>Feedbacks</td>
<td>A basic factor to improve performance is to have feedback about the actions that have been done. Giving positive feedback to users completing successfully an exercise, or cheering up a user who ran out of time fulfills the motivational part. Giving feedback involves providing specific information about the user condition, environment, progression and achievements as well.</td>
</tr>
<tr>
<td>Real time scoring</td>
<td>TANGO-H shows the user the score on the game in real time as it is shown live on the screen.</td>
</tr>
<tr>
<td>Success effect</td>
<td>Any time a user finishes a phase of an ongoing exercise, a success effect is shown to let the user realize it. In this case it is visualized as a shaded glow filling the screen in blue.</td>
</tr>
<tr>
<td>Achievements</td>
<td>When a user achieves something remarkable or to be considered a milestone, an achievement might be unlocked. An achievement is therefore a virtual or physical representation of the milestone. There is usually a panel of locked achievements the user knows and might want to unlock. In TANGO-H stars can be obtained if the user gets high scores on exercises.</td>
</tr>
<tr>
<td>Levels</td>
<td>Levels are also an indicator of status in a community related to the level of expertise, comprehending from experts to beginners. TANGO:H defines difficulty levels to adjust to user profiles, their characteristics, skills and evolution. The exercise have parameters to adjust difficulty such as time, action range and target size.</td>
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<tr>
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</tr>
<tr>
<td>Timing</td>
<td>Users have to stay still while activating targets in TANGO:H in order to make actions be recognized. Timing parameter can be assigned to exercises. Users have a time factor which linearly modifies the exercise parameter adapting it to his preferences. The user gets immediate feedback of the activation timing with a completion wheel shown on the screen.</td>
</tr>
<tr>
<td>Action range</td>
<td>TANGO:H allows the definition of the precision necessary to activate objectives, measured as distance from the activating body joint to the center of the target. This parameter can be adjusted in every exercise, and it is modulated with a factor parameter in the user profile. This allows the definition of difficulty levels for an activity.</td>
</tr>
<tr>
<td>Target resizing</td>
<td>The targets included in TANGO-H can be resized on screen. The size of the targets can make them easier or more difficult to reach. Therefore, difficulty levels can be implemented using the resizing of targets as a parameter.</td>
</tr>
<tr>
<td>Avatar's Customization</td>
<td>Each user in TANGO-H has a customizable avatar as a representation. The customization increases the immersion and the feeling of affection for the character.</td>
</tr>
<tr>
<td>User satisfaction</td>
<td>After each exercise is finished in the platform, the user has the possibility to give feedback about his satisfaction. A set of emoticons belonging to different emotional categories are shown. The number of emoticons to choose from varies depending on the alleged age of the user.</td>
</tr>
<tr>
<td>Rewards</td>
<td>TANGO-H provides the user with a game system that encourages the user to improve their trajectory in the game by using a reward system. Users activity will be reflected through prizes which will be obtained exchanged for points. During the execution of an exercise the achievement of objectives is transformed into stars that are accumulated with each new goal achieved. The user or group can access then the prize gallery where there will be shown a list of prizes with their value in stars. When the user or group decides to buy a prize, the price will be subtracted from its stars and the prize may be viewed at any time in its prize gallery afterwards. With the intention of keeping the user informed about the prizes that can be unlocked after the end of the exercise, as well as facilitating access to the prize gallery, there is a pop-up window in the application, called “Available prizes”. This window is superimposed on the results screen of the exercise only if the user or the group that participated in the exercise have enough stars to buy or unlock any of the blocked prizes in the prize gallery.</td>
</tr>
</tbody>
</table>
Sound

Sound is a fundamental part in any game because it transmits different sensations to those received by sight. In addition, it helps not only to capture the user's attention, but also to keep him attentive throughout the exercise. Users can choose the background sound from a list or if none has been selected, the default sound is used automatically. The tempo of the background sound is accelerated to inform the user that time is running out. This makes the experience more complete, because, in addition to adding tension and emotion, the user can know at any time the remaining time of the exercise, by means of a label that shows it and the sound tempo.

Progress bar

With the intention of showing the user at all times the progress of the exercise, a progress bar indicate graphically, the percentage of completed tasks. This element, the timer and the acceleration of sound provide the user very complete information about the development of the exercise.

Best moments

The best moments consist in showing at the end of each game, different photos of the players made during the game. It is a fun feature that motivates the participants during the game, feeding their curiosity to see the movements they have had to complete, as well as receiving support from the platform, due to the phrases shown.

5. Towards a smart system for rehabilitation games

5.1. TANGO:H Designer. Designer experience

One of the most outstanding features of TANGO:H is allowing users to design the activities to be run in the platform afterwards, using a drag and drop editor tool. All the information needed during the runtime to execute an activity and the metadata with extra information is associated to it by the designer. An example of this metadata is the difficulty levels associated with each activity.

Moreover, it has been also defined as metadata a set of skills which are associated to both activities and users. Each of these skills are evaluated using a number in the range from 0 to 1. The skills associated with the user creates the user model, and represent the system estimation of each user skills development. At the same time, skills related with the activities represent the expected skill mastery necessary to successfully complete the activity.

Everytime a user finishes an activity, the skills values associated with his user profile are updated. New skills might be associated with the model if the user had not an association with a skill that the activity did have. This model allows the platform to select which activities are the most appropriate for a user at any moment. The recommender system function is explained later.

The user model update can be succinctly described as follows:

- In the cases the users successfully complete the activity:
  - If the user already has a skill valuation: The value is generally moved upwards.
  - If the user model does not contain that skill information yet, the skill is assumed to be learned, and a new valuation is assigned to the user model.
- In those cases, when the user could not successfully complete the activity:
  - If the user already has a skill valuation: The value is generally moved down.
If the user model does not contain that skill information yet, the skill might be still valued and added to the user model, depending on the results achieved in the unsuccessful attempt to complete the activity.

According to the general principles stated above, the user model update has been built into a system upgrade module that makes easy for any developer to modify the user model upgrade policy without interfering with the rest of the platform. As proof of concept the next formula has been implemented.

**Formula:**

\[
Value_{Skill} = Value_{Skill} \cdot (1 - Value_{Skill-Activity} \cdot (1 - \gamma)) + NormScore(\text{Player}) \cdot (Value_{Skill-Activity} \cdot (1 - \gamma))
\]

Where:

- \( \gamma \): Is a discount factor that makes the system forget part of the previous evaluation of the player skills to be updated.
- \( NormScore \): Are the normalized results of the user calculated as the average of the maximum value obtained for that activity divided by the maximum value that might be achieved for the activity.

The result of applying this formula is used to update the user profile stored at the DDBB. The update might include, as stated before, either new values associated to the user profile, or an update of previous values.

When new users are created on the platform, there is the possibility to make a user profile initialization, assigning some initial values to a selection of skills associated with the user, and easily selecting the actual value moving a slider (Figure 1).

There is additional metadata associated with each user, which can be transferred to the TANGO:H player app the user would use. This data, which can also be exported to a normalized format, includes:

- Personal Information: Name, date of birth, and sex.
- Game playing information: Action range, timing, target resizing and the number of successfully completed activities.
- User group.
- Achieved level.
- Skill set valuation.
- Assigned activities.
- Events log, etc.
The designer screen also allows to include metadata associated with each activity. There is a preset number of predefined skills, but new ones might be added at any time. The designer is able to produce normalized exports of the designed activities to be imported in any TANGO:H player.

5.2. Recommender System

The platform allows a super user to decide the set of activities that are going to be available to the final user. Nevertheless, if the user were always set free to choose the activity of his preference it might not follow the most interesting option for his skills development. It might be the case that the chosen activities result either too easy for the user, turning the game into a boring task to complete, or either too difficult, frustrating the user. The recommender system associated with TANGO:H player might alleviate this circumstances, selecting the appropriate activities regarding the user skills and profile history.

Analyzing the results the user achieved in the last activities which has been attempted, and the number of times that were successfully completed, different recommendations can be constructed (Figure 2). If the number of successful activities is low the system should recommend easier activities regarding the user’s skill valuations and the activities requirements. Alternatively, if a player is successful too many times in a row, before he could start to be bored, the system should recommend a tough activity which should become a new incentive and challenge for the user to improve himself. As a result, it can be stated that the implementation of the recommender system can be designed as closed-loop control system regarding the activity difficulty with the aim to keep it slightly over the difficulty level already acquired by the user (Figure 3).
Figure 2. Feedback to users including skills of users and required, reasons of the recommendation and skills affected.

Figure 3. Personalization of level in TANGO:H Designer
5.2.1. Scenario 1

A particular case of implementation of such a recommender system is described below. Firstly, the skills valuations of the user model are subtracted from the required skill levels of an activity. A negative value indicates the user would find difficulties to complete the activity due to that specific skill. On the contrary, a positive value determines a relative advantage of the user to do the activity.

In our particular example we observe that the user has developed some of the skills required by the activity but not all of them. As a consequence, the user might be able to incorporate new skills to his user profile if he is able to complete the task, because he has to demonstrate having developed them to fulfill.

- Speed: The activity requires a value of 0 and the user already has a valuation of 0.4. Therefore the user is 0.4 over the minimum required.
- Equilibrium: The activity requires 0.1 and the user has 0.5. Again the user valuation is over what should be required.
- Coordination: The activity requires 0.6 and the user has 0.8. In this case the user has also more than the required skill but now the margin is tighter.
- Reflexes: The activity requires 0.4 but the user does not have any reflexes valuation in his user model. Equivalently the user has a 0 valuation, and therefore the requirements are above the user skills, which means the user has to learn it.

In the described context the user outperforms the requirements in three out of four required skills and the only skill in which falls behind is not highly valued for the activity. The overall sum of differences between requirements and skills is positive and equal to 0.6. This means that the activity is not expected to be especially difficult to the user and may be recommended even when the recent history of the user shows a low ratio of successfully completed activities.

5.2.2. Scenario 2

- Speed: The activity requires a value of 0.7 and the user already has a valuation of 0.4. Therefore the user is 0.3 under the minimum required.
- Equilibrium: The activity requires 0.2 and the user has 0.3. Again the user valuation is 0.1 over what is required.
- Coordination: The activity requires 0.7 and the user has 0.8. In this case, again, the user has also 0.1 more than the required.
- Reflexes: The activity requires 0.8 but the user does not have any reflexes valuation in his user model. Equivalently the user has a 0 valuation, and therefore the requirements are way above the user skills.
- Agility: The activity requires 0.4 but the user does not have any agility valuation in his user model. Equivalently the user has a 0 valuation, and therefore the requirements are slightly above the user skills, and it is assumed the user might acquire the required skill.

In this scenario the user only covers two of the five required skills, and furthermore one of the required skills is quite above the user valuation. The overall disadvantages of the user add up to 1.3. The system expects this activity to become a challenge to the user and only could be appropriated to be recommended in those cases where the number of successful activities in the last record of the user is high.

The recommender system would start sorting the list of activities using the relative difficulty expected. The application TANGO:H player would decide a difficulty number based on the user profile and history record. Based on this number which is directly associated with a difficulty level, the recommender would select the most appropriated activity from the list.

The difficulty level calculus based on the user history record is denominated ‘emotion’ calculus. It is assumed that the ‘emotion’ increases with each successfully completed activity.
and, on the contrary, it is reduced after a failure. Nevertheless, as it has been already stated, always winning would also penalize ‘emotion’. A low ‘emotion’ level for either cause, always failing or been successful would lead to the user abandon.

Based in this principle, the ‘emotion’ calculus can be computed as follows. The result of the last activity is checked on the first place. Then the last N results are compared with the last one. If the number is above a certain threshold means the user has been failing or succeeding too much during the last activities. On either case the ‘emotion’ estimate is going down. If the tendency is to succeed the user would need a challenge and the difficulty level is increased. On the contrary if there is a negative tendency, the difficulty level would be lowered to avoid frustration. If there is an even number of successes and failures, the difficulty level could be considered appropriate, and the same level of intermediate difficulty would be kept, since that level supposes a challenge for the user which still seems able to fulfill.

As a summary of the theory exposed above, the difficulty level adjust could be defined as:

- Less difficult level: Lasts results are negative with a large proportion of failures.
- More difficult level: Lasts results are positive with large proportion of success.
- Keeping difficulty level: Lasts results are a combination of successes and failures.

5.3. Level Mode System in TANGO:H. Player Experience

Not all user would like to be pressed to improve in the same way or rate. The level mode system allows more player oriented recommendations, based on the user preferences, chosen in his profile, and increases playability. The goal of this system is to influence the coping capacity of users, making them willing to continue playing seeking self-improvement and overcoming circumstances. To implement this system, three different levels have been defined. The number of levels could be, nevertheless, increased as a setup parameter.

- Beginner: This level corresponds to the initiation of the user in the platform. All novel users should start in this level which is associated to the most basic activities with lower requirements, which will be increased slowly along with the user.
- Intermediate: After a certain number of successful activities from the Beginner level the user might choose to be considered as intermediate. The potential difficulty level is increased and they would require more intense action from the user.
- Expert: At this level the maximum requirements are asked to the user. The level only can be chosen after a certain number of positive experiences with intermediate activities. The most difficult and challenging activities would belong to this level, which are only appropriate to experienced users with high developed skills.

At the moment that a player has to choose the activities with which he wants to interact, only those activities belonging to a level mode equal or lower to the one that he has at that moment is shown. Consequently, a level one user would only access to level one activities. On the contrary, level three users would be able to access activities of any level. The user has always visible in his profile the level mode selected at that moment. Currently it is shown in the form of golden crowns associated with the user profile.

Some activities are considered as borderline activities. This means that the difficulty level of them is quite close to the difficulty of activities of the next or previous level mode activities. The number of these activities the user has completed or failed are counted. Whenever the count is above a certain level the user level mode is changed.

Independently of the game mode the user has chosen, either single player mode or multiplayer mode, the users levels would be updated. This means that multiple users might update level mode at the same time.
5.3.1. Game modes

Based on the recommender system described below, different strategies to choose the next activity have been defined. This election is named ‘Game Mode’. The final user would be able to choose at any time the game mode that better suits his interests.

5.3.2. Guided Game Mode

During the user interaction, it would be the system itself the one who chooses the activities the final user has to deal with. To be able to make this decision the system would use the described recommender system, based on the level mode of the user.

The user might have been associated with a complete list of potential activities, by a tutor, expert or domain professional. Each time an activity is completed successfully, it disappears from the list of candidate activities to be recommended. If the user fails, however, the activity might be eventually chosen again by the recommender system. When the user completes all activities from the list, he gets to the congratulations screen before being sent to choose game mode again.

5.3.3. Free Play Game Mode

When the user selects this game mode, the recommender system still will recommend the next activity to the user. Nevertheless, in this case the user can decide whether to follow the system recommendation or to choose any other activity from the list of selected activities associated with the user.

In order to create a transparent as well as easy to understand system, a feedback window will give the user information about the reasons why the recommended activity has been chosen.

The user will have access to the valuation of skills of his profile and the requirements of the activities available. Information about the reason to choose a particular activity as recommended and the skills valuations that would be increased is also shown to the user.

6. Tango-H for rehabilitation

We detail now how TANGO:H can be used as a rehabilitation tool. Into a rehabilitation plan, we might distinguish different types of particular objectives. Firstly, we might focus on physical mobility recovery and muscle strengthen associated with some specific body joint. Alternatively, after a neuronal/cognitive affection the rehabilitation might include exercises to recover movement coordination a cognitive process (Figure 4). In both cases, the patient should understand the concepts related to the process going on to have better understanding of the recovery process and the expected physical evolution. The patient should also know the limitations that is facing as a consequence and the ways to choose better strategies for the rehabilitation process.

6.1 Goals

At each of these scenarios mentioned above, TANGO:H might define a different approach towards achieving the goals:

a) Regarding the physical rehabilitation:

- It should be pointed out that the body movements that are suitable to be recognized by the applications are those that project into a surface perpendicular to the sensor axis. Therefore, the person should stay in a frontal position with respect to the screen. In this position, consequently, it is especially relevant the movements that are done with the shoulder, elbow and hips.
Using TANGO:H we can force the user to make a pure joint movement. This is, movements that involves the movement of a joint along only one axis. Usually this kind of movement affects only one muscle group. Otherwise, the application can also force the user to do functional movements. This other type of movement seeks to fulfill an action or reach a goal, and therefore it is usually necessary to make a combination of movements from different joints, or a movement along different axis within the same joint.

The difficulty of the movement is clearly related with the time available to complete it. The application allows to control the different times the user have to complete the activities and movements, and therefore the exercise parametrization.

Furthermore, the precision that it is required to the position of the body in order to accept every movement can be adjusted, for each initial or end point of the movement. This can obviously change how hard or easy each exercise is. TANGO:H controls this setup measuring the distance of the body point to the center of the pretended goal on screen.

Different tangible goals to reach are set up to appear sequentially on screen one after the other. The way those sequences are built are also directly defining the difficulty to complete the activity. Much more effort has to be made to reach goals located far from each other at every step with respect to other situation in which they appear one close to the next.

b) Regarding the cognitive rehabilitation:

Being able to see your own body represented on screen and with the possibility of drawing on top of it the exact position reached by each joint allows and makes easier the body awareness and positioning, which is a first step towards a better movement coordination.

The tool also allows to establish different goals to be reach and activated necessarily simultaneously. In these situations the movements to be done have to be coordinated or otherwise the activity would not be registered as satisfactory. Therefore, this activities are pure coordination movement exercises.

In this case, not only time and precision but also the number and distance of goals to reach simultaneously becomes now a parameter to set the exercise difficulty.

The platform allows us to set up ‘goals to avoid’. In this occasions there are regions of the screen in which the user should never position some specific parts of the body. This allows the exercise to force the user to find trajectories on space to move along, and therefore not any intermediate position between goals is allowed for the body, and the movement coordination should be improved.

c) Regarding new knowledge acquisition:

Because the activities to be completed can be scheduled over time, it is possible to determine as well the best moments on time when the user can be better off if exposed to new concepts or information. It is well know that after being exposed to new knowledge for the first time, a person needs some time to internalize the information. After this time, it is usually recommended to have a reminder to avoid the brain from forgetting the new information. Some additional reminders could come in subsequent moments of time. Those exact moments could be computed in advanced and incorporated into the activity plans for the best performance on the user learning curve.

The creation of what is called cognitive activities on TANGO:H allows to introduce information pills inside the activities. That information could be, or not, related with the rehabilitation process itself. At some selected opportunities could be convenient to
make reminder activities as mentioned earlier, and in other cases the most convenient could be to distract the user attention from the rehabilitation process. This might allow increasing the activity periods in which the user is willing to use the application, reduce the mental fatigue, and potentially the stress the person goes through. At the same time, after the distraction activity, the attention and intensity to the following activities would increase significantly.

d) Motivation:

- The application can show screenshots to exhibit how the user interacted with the system in previous occasions. This allows visualizing the progress that might have taken place in a certain period of time, and incentivizing the user to continue using the platform.
- Despite the activities have to be adapted to each user mainly focusing on the rehabilitation goal to be achieved, there is also room for further ‘theme’ personalization. This ‘theme’ can be selected regarding interests and personal preferences of the users. The activities use images to help the user locate the goals to reach with each movement, sounds are played, descriptions are displayed, etc. All these elements can be used to build a narrative about certain topics, or simply contextualize the exercise with some appealing items to users. This contextualization might also depend on the user, task, and difficulty level, and might be an additional motivation to the user to get or continue involved with the tasks.

Figure 4. TANGO:H has been used for neurorehabilitation in the Completo ACAMAN during 2018.

6.2. Recommender System for Rehabilitation

The recommender system incorporated in TANGO:H, can be adapted naturally to be used in the context of rehabilitation. This is, the approximation to a recommender system described previously in the article continues to work in this context. There is only a terminology difference
in the way the system works. Firstly, the skills to be developed are not skills related to an academic curriculum, but with the rehabilitation process. In the case of physical rehabilitation, each skill will be defined as a joint or a mobility range to be reached. The type of movement to be performed within the mobility range, for example muscle extension, will define different types of activities for that skill. In the case of cognitive rehabilitation, skills are defined in terms of the combination of movements and joins that are involved.

- Furthermore, the recommender system should define a set of difficulty levels to be able to adapt the activities to each user at each moment. These difficulty levels can be defined using the activity parameters that have been already stated while defining TANGO:H as a rehabilitation tool. It includes:
  - Available time to complete each movement.
  - Movement precision for goal recognition.
  - Goal resizing.
  - Objects to avoid on screen between the desired goals.
  - Activity duration.
  - The number of movements involved in coordination tasks.

With all the above mentioned elements the recommender systems designed generally for TANGO:H can provide valid recommendation in this new context of usage.

7. Results

We have developed a pilot study with children from 8 to 12 years old and with 5 experts from the different areas (psychology, physiotherapy, physical education, computer science, motor games) (Table 2). The main goal of this study was the analysis of the playability’s aspects and the emotional and social interactions with TANGO:H.

In the experts evaluation we applied the playability instrument created by Gonzalez-Sanchez et al [37] after one session of one hour with experts using TANGO:H. Results are shown in Table 3 and Figure 5.

Table 2. Experts’ age, gender and area of expertise

<table>
<thead>
<tr>
<th>Experts</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>E5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>Motor games</td>
<td>Education</td>
<td>Physiotherapy</td>
<td>Psychology</td>
<td>Human Computer Interaction</td>
</tr>
<tr>
<td>Age</td>
<td>57</td>
<td>46</td>
<td>58</td>
<td>33</td>
<td>43</td>
</tr>
<tr>
<td>Gender</td>
<td>M</td>
<td>M</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
</tbody>
</table>

F: Female – M: Male
Table 3. Results of expert evaluation on TANGO:H’s playability.

<table>
<thead>
<tr>
<th>Playability /Dimensions</th>
<th>Satisfaction</th>
<th>Learning</th>
<th>Effectiveness</th>
<th>Immersion</th>
<th>Motivation</th>
<th>Emotion</th>
<th>Socialization</th>
<th>Media</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intrinsic</td>
<td>3.90</td>
<td>4.43</td>
<td>3.50</td>
<td>4.29</td>
<td>3.63</td>
<td>4.20</td>
<td>3.00</td>
<td>3.85</td>
</tr>
<tr>
<td>Mechanical</td>
<td>3.71</td>
<td>2.33</td>
<td>3.00</td>
<td>3.50</td>
<td>3.00</td>
<td>4.00</td>
<td>2.33</td>
<td>3.13</td>
</tr>
<tr>
<td>Interactive</td>
<td>4.67</td>
<td>4.23</td>
<td>4.00</td>
<td>4.45</td>
<td>3.50</td>
<td>4.57</td>
<td>2.67</td>
<td>4.01</td>
</tr>
<tr>
<td>Artistic</td>
<td>4.00</td>
<td>4.67</td>
<td>3.00</td>
<td>4.20</td>
<td>3.67</td>
<td>4.00</td>
<td>3.33</td>
<td>3.84</td>
</tr>
<tr>
<td>Personal</td>
<td>4.43</td>
<td>4.00</td>
<td>3.60</td>
<td>4.45</td>
<td>3.75</td>
<td>4.75</td>
<td>3.67</td>
<td>4.09</td>
</tr>
<tr>
<td>Social</td>
<td>3.67</td>
<td>4.33</td>
<td>4.33</td>
<td>3.00</td>
<td>3.50</td>
<td>3.50</td>
<td>3.40</td>
<td>3.68</td>
</tr>
<tr>
<td>Media</td>
<td>4.06</td>
<td>4.00</td>
<td>3.57</td>
<td>3.98</td>
<td>3.51</td>
<td>4.17</td>
<td>3.07</td>
<td>3.77</td>
</tr>
</tbody>
</table>

Figure 5. Summary of results on Tango H playability.
Regarding the pilot study with children, the sample consisted of 24 children aged between 8-12 years old. The experiment was developed during 8 weeks, with two group sessions by week, using TANGO:H (20 minutes). The sessions were videotaped with the goal to conduct an structured observation process at the end of the sessions. Two videos were recorded, one of the children’s faces and another of their interaction with the system. The two videos were then combined using software specifically designed to analyze sports videos, which features specific components for analyzing group physical activities (labels, categories, subcategories, teams, players, etc.) that facilitate our structured observation of the groups engaging in active videogames. In our case the software used was LongoMatch. The recordings were observed by three evaluators from different areas such as psychology, computer engineering and education, who then analyzed the agreement in the categorization and codification decisions. The three observers carried out the categorization following the observer’s guide presented in Table 4. A total of 3465 registers on interactions using TANGO:H has been observed and analyzed.

Table 4. Guide for the observation

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Criteria</th>
<th>Relationship with the emotional categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-verbal language</td>
<td>Descriptive gestures (associated with the task, such as “V” for “victory”)</td>
<td>Categorized into positive, negative and ambiguous</td>
</tr>
<tr>
<td></td>
<td><strong>Facial expressions</strong></td>
<td><strong>Categorized into positive, negative and ambiguous</strong></td>
</tr>
<tr>
<td></td>
<td><strong>Facial expressions</strong></td>
<td><strong>Categorized into positive, negative and ambiguous</strong></td>
</tr>
<tr>
<td></td>
<td>Where the eyes are looking, for example downward if the student is distracted or to avoid a conflict.</td>
<td>Categorized into positive, negative and ambiguous</td>
</tr>
<tr>
<td></td>
<td>Emotional gestures:</td>
<td><strong>Categorized into positive, negative and ambiguous</strong></td>
</tr>
<tr>
<td></td>
<td>· Reduce tension: fix one’s hair, scratch, etc.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· State of conflict or negative emotions: sucking one’s thumb</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· Fatigue: touching one’s hair or ears, yawning</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· Aggressiveness: leaning forward</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· Empathy: imitating another</td>
<td></td>
</tr>
<tr>
<td></td>
<td>· Other</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Touch: physical contact between the children, they feel nervous or upset</td>
<td>Categorized into positive, negative and ambiguous</td>
</tr>
<tr>
<td>Aspect</td>
<td>Criteria</td>
<td>Relationship with the emotional categories</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>---------------------------------------------</td>
</tr>
</tbody>
</table>
| **Verbal language**| Positive: Hahaha! Yes! Take that! Alright! When do we start? I want to play too! Very good! Good job! Come on! Keep it up!, etc.  
  - Negative: Nooo! Damn! Grrr! Boo! Damn! Geez! Pass! I can’t! I don’t know how! I don’t want to! I feel bad! I’m so nervous!  
  Ambiguous: Quiet! I’m sorry! I’ll help you! Too bad! Are you ok? I hope so! We’ll see!  
  4. - Duration or time required | Categorized into positive, negative and ambiguous  
  Their intensity will also be categorized as high, medium or low. |
| **Social interaction** | -Types of interactions:  
  1. Interacts with observers (IO): the participants ask questions, ponder, etc.  
  2. Observer-triggered behavior (OTB) – if the observers’ comments trigger both verbal and non-verbal conduct in the players.  
  3. Shared experiences (SE): the players share experiences with others, reflecting an expressive behavior (such as laughing together)  
  d) Cooperation (COO): some players shared advice and helped one another overcome obstacles.  
  e) Competition (COM): the players competed, for the highest score for example.  
  f) Failed attempts at interaction (AI): a player tried to interact but another player ignored him/her. | Categorized into positive, negative and ambiguous |

Results are presented below based on three aspects noted by observers watching the video: non-verbal language (Table 5, Figure 6), verbal language (Table 6, Figure 7) and any social interactions (with classmates or with the professional/observers) (Table 7, Figure 8) that took place when interacting with TANGO:H.
Table 5. Non verbal language

<table>
<thead>
<tr>
<th>Type</th>
<th>Non verbal expressions</th>
<th>Facial Expressions</th>
<th>Glances</th>
<th>Emotional Gestures</th>
<th>Touch Feel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>83 18%</td>
<td>492 80%</td>
<td>31 14%</td>
<td>145 41%</td>
<td>38 58%</td>
</tr>
<tr>
<td>Negative</td>
<td>33 7%</td>
<td>99 16%</td>
<td>7 3%</td>
<td>34 10%</td>
<td>13 20%</td>
</tr>
<tr>
<td>Ambiguous</td>
<td>337 74%</td>
<td>24 4%</td>
<td>176 82%</td>
<td>177 50%</td>
<td>15 23%</td>
</tr>
<tr>
<td>Total</td>
<td>453 100%</td>
<td>615 100%</td>
<td>214 100%</td>
<td>356 100%</td>
<td>66 100%</td>
</tr>
</tbody>
</table>

F: Frequency

Figure 6. Non verbal languages frequencies observed
Table 6. Verbal expressions

<table>
<thead>
<tr>
<th>Emotional category /Arousal</th>
<th>Positive</th>
<th>Negative</th>
<th>Ambiguous</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>%</td>
<td>F</td>
</tr>
<tr>
<td>High</td>
<td>57</td>
<td>23%</td>
<td>32</td>
</tr>
<tr>
<td>Medium</td>
<td>107</td>
<td>42%</td>
<td>109</td>
</tr>
<tr>
<td>Low</td>
<td>88</td>
<td>35%</td>
<td>194</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
<td>100%</td>
<td>335</td>
</tr>
</tbody>
</table>

F: Frequency

Figure 7. Results of verbal expressions observed

Table 7. Social Interactions

<table>
<thead>
<tr>
<th>Types of social interactions</th>
<th>F</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interactions with the observers (IO)</td>
<td>331</td>
<td>23%</td>
</tr>
<tr>
<td>Behaviors triggered by the observers (OBT)</td>
<td>725</td>
<td>49%</td>
</tr>
</tbody>
</table>
## Types of social interactions

<table>
<thead>
<tr>
<th>Types of social interactions</th>
<th>F</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sharing experiences (SE)</td>
<td>126</td>
<td>9%</td>
</tr>
<tr>
<td>Cooperation (COO)</td>
<td>216</td>
<td>15%</td>
</tr>
<tr>
<td>Competitiveness (COM)</td>
<td>18</td>
<td>1%</td>
</tr>
<tr>
<td>Failed interaction attempts (IA)</td>
<td>50</td>
<td>3%</td>
</tr>
<tr>
<td>Total</td>
<td>1466</td>
<td>100%</td>
</tr>
</tbody>
</table>

F: Frequency

![Figure 8. Results of social interactions behavior observed](image)

Moreover, the level of difficulty of each exercise was considered and tagged. So, two levels of difficulty were identified: normal (42.66%) (for example, using hands to touch the goals) and high (57.34%) (for example, needs to use feet and collaborating with other player to solve the exercise).

As results of the pilot study it is possible to note the following:

- About the playability, it has been evaluated in a scale of (1-5) the aspects of satisfaction (4.96), learnability (4.00), effectiveness (3.57), immersion (3.98), motivation (3.51), emotion (4.17), social (3.07). We can note that six of the seven aspects are satisfactory (>=3), with a value media in average of 3.77.
- Related to the emotional aspects founded in the experiment, we have observed different behaviors (non verbal, verbal language and social interactions) corresponding to the distinct
exercises in TANGO:H and categorized in different emotional categories. In nonverbal behaviors the observers found a high of ambiguous emotions and positive emotions. The highest positive emotion observed corresponding to the type of “touch feel” (58%), maybe due the characteristics of the own TANGO:H.
- About the verbal language observed, the negative expressions have the highest value (42%), followed by positive expressions (31%) and ambiguous expressions (27%). This results can be explained by the expressions of users used when they fail and must try again.
- Regarding the results of the observed interactions in the 3465 registers, we found the following frequencies percentage: IO (~23%), OBT (~49%), SE (~9%), COO (~15%), COM (~1%) and AI (~3%). We can note that the highest frequency was for interactions with observers (IO and OBT) following for cooperation behaviors (COO), instead of competition or ignore interactions with others.

8. Discussion

In this paper we have described TANGO-H platform, where the user's interaction with the system is done through the human body and the recognition of gestures, without the need of having physical contact with traditional control systems, but using KINECT sensor. The TANGO-H project started as a platform in which users selected which exercises to perform. Player experience has been improved including gamification and a recommender system. Gamification incorporates a system of levels that control user access, preventing them from choosing exercises that exceed their current capabilities. It has been also implemented a system of skills to control the evolution of the user and a recommender system has also been created. The playability of the system has been validated. First, through to a expert evaluation using playability heuristics and dimensions. Then, a pilot study with children using the platform has been carried out. Afterwards, the player experience has been evaluated making structured video analysis of videotapes of a whole real intervention with children. Results have been presented in the paper showing the emotional reactions and the social interactions triggered by the platform use.

Although this platform has been created with the mail goal to be used with hospitalized children, it has been used for other rehabilitation, health and educational goals in different institutions such as: San Fernando Duggi School, Santa Cruz of Tenerife, Hospital Classroom of the University Hospital of the Canary Islands (HUC), Hospital Room at the Dr. José Molina Orosa Hospital in Lanzarote, Down Tenerife (Tenerife), Centro Socio Sanitario Nuestra Señora del Carmen, Unit of brain damage (Valencia), CEIP Santa Rosa de Lima (Tenerife), CEIP Las Mercedes(Tenerife), CEIP La Verdeillada (Tenerife), CEIP Agüere (Tenerife), CEIP La Aneja (Tenerife), CEIP Samoga (Tenerife). For research purpose, TANGO:H is being using in Ecuador for the Universidad Técnica Particular de Loja of Ecuador, or in the University of Almería. In the Basque Country, in the Arizmendi School, it was used as a tool to prevent childhood obesity. The platform has also been used in older people through the company Gestión de Servicios Residenciales GSR-S.Coop of Mondragón, Basque Country. Also, TANGO:H is being currently used for neurorehabilitation in the ‘Complejo ACAMAN’ (Tenerife).

As an open line for research, in the future of the platform exercises could be tracked even closely in order to capture every movement of the user being carried out. A study on those parts of the body with which it shows greater difficulty, could be easily performed and presented afterwards. Consequently, the specialist will be able to observe those areas in which the patient improves or where the treatment should have more impact. In addition, since the Kinect provides a great capacity of control of the user's joints, the use of gesture capture can be used to carry out a satisfaction study of the application or be used to create exercises
for those with other problems such as facial paralysis. In this way they will perform exercises that would help them to control movements in their face again.

The recommendation system could be expanded by taking advantage of the capabilities provided by Kinect, storing a more detailed study on the results obtained for each part of the body of the user. This could be used to recommend exercises that work out these areas. It could also store the areas of the body with which the user touches the objectives, in addition to adding new capabilities to the system with the user's gestural capture, which could benefit the recommender system through the use of this ability to take into account also the user's emotions.

From the point of view of the exercise designer, a statistics system could be implemented to have a detailed study of the evolution of the user. In addition, each designer should have the possibility to share their exercises created through the Internet, so that other users can download them. This could facilitate the work to specialists who could download work packages for users (by levels, areas with which work, etc.).

References


