Digital-Pheromone Based Difficulty Adaptation in Post-Stroke Therapeutic Games

Abdelkader Gouaich, Nadia Hocine, Liesjet van Dokkum, Mottet Denis

Digital-Pheromone Based Difficulty Adaptation in Post-Stroke Therapeutic Games

Abdelkader Gouaïch*, Nadia Hocine*
LIRMM Laboratory
(Montpellier II University, CNRS)
161 rue ADA, 34095
Montpellier, France.
{gouaich, hocine}@lirmm.fr

Liesjet Van Dokkum**, Denis Mottet***
Movement to Health Laboratory
(Montpellier I University)
700 Avenue du Pic Saint Loup, 34090
Montpellier, France.
{mottet, van-dokkum}@univ-montp1.fr

ABSTRACT
In this paper, we propose a dynamic difficulty adaptation approach for serious games dedicated to upper-limb rehabilitation after stroke. The proposed approach aims to provide a personalized rehabilitation session in which the training intensity and challenges can be adapted to patient's abilities and training needs. The objective is to increase the rehabilitation volume by getting the patient engaged in the therapy session. This approach has been implemented and tested through a point and click game. It has been also experimented on healthy people in order to explain how this approach will be integrated to post-stroke therapeutic games.

Categories and Subject Descriptors
I.2.1 [Applications and Expert Systems]: *Games*

General Terms
Design

Keywords
Difficulty adaptation; post-stroke rehabilitation; serious game.

1. INTRODUCTION
Stroke is a medical emergency that can cause permanent neurological and functional damages. It can cause amongst others hemineglect, the inability to move one or more limbs on the controlateral side of the body and to understand or formulate speech. The specific abilities that can be affected by stroke depend on the location, type and size of the lesion. Each patient is characterized by a specific combination of deficits.

Most rehabilitation techniques are founded on the principles of motor learning and skills' acquisition established for the healthy nervous system. Several studies suggest that intensive training (many repetitions) while giving feedback and motivating patients can have an important impact on their motor skill recovery [3] [10]. During rehabilitation sessions, therapists try to improve patients' functional skills by defining a set of exercises to reach or grasp objects in a 2D work plan. Therapists try to train patients by adapting the activities to the patient's abilities and current health condition.

IHI'12, January 28–30, 2012, Miami, Florida, USA.

Therapeutic games or "theragames" may be considered as useful rehabilitation tools as they allow personalizing the rehabilitation session according to the patient's abilities and training needs. In fact, theragames provide an environment in which the training intensity, difficulty, duration and frequency can be manipulated and enhanced. They also offer the opportunity for therapists to monitor and analyze rehabilitation sessions. In addition, theragames have to fulfill game design principles and rules as well, in order to be entertaining and engaging while serving their pedagogical/therapeutic purposes.

Our objective is to propose a dynamic difficulty adaptation (DDA) technique dedicated to a family of post-stroke therapeutic games. This technique focuses on a digital-pheromone based algorithm that is used to assess and track the patient's movement capabilities.

In the following section, we will discuss theragames key challenges that have been identified by our research activities with therapists and researchers from different hospitals in Montpellier and the Movement to Health laboratory. Then, we provide readers with the state the art of difficulty adaptation in therapeutic games. In the fourth, section we describe the proposed adaptation technique as well as the digital-pheromone based algorithm. After that we will explain how this approach has been implemented by a simple training game. The six section aims to describe the pilot experiment we have conduced to control for the effectiveness of the adaptation technique in terms of motivating players. Finally, we conclude the paper by discussing the results of the pilot experiment and explaining our contribution regarding the related work.

2. POST-STROKE THERAGAMES CHALLENGES AND REQUIREMENTS
Theragames may be considered as a promising rehabilitation tool, especially in post-stroke rehabilitation context. The usefulness of such tool can be can be established by overcoming adequately the challenges identified by: (i) the medical aspects of the therapy and (ii) the technical, psychological and creative aspects of the game.

From a therapeutic point of view, the theragame should provide a motivating rehabilitation environment allowing for the manipulation of training duration, intensity and frequency. In addition, a theragame should take into account patients' abilities and training needs in order to provide them with a personalized game experience. Actually, each patient can be characterized by a specific combination of deficits and has a particular recovery rate. Therefore, theragames should be adaptive to the patient's observed abilities, performances and her or his health condition.

Another challenge identified, is the accessibility of the theragame. In fact, stroke patients would need different devices depending on their stage of recovery and rehabilitation. For instance, during the first weeks of their rehabilitation program, patients often cannot grasp an object due to their motor deficits. Thus, the theragames devices that should be anticipated for rehabilitation are for instance: motion capture based devices, IR sensors, graphic tablet, wii-board, kinect, etc.

From the game design point of view, it is important to create a game without being too much constrained by therapeutic requirements. In fact, creativity and imagination are very important in the game design to provide meaning to both gaming and therapeutic tasks. Allowing thus to create an engaging experience for the patient.

Indeed, as a stroke causes long-term impairments, it is important to build several games (and consequently try to reduce the development costs) or imagine game scenarios that can sustain several months of rehabilitation. It is necessary to mention the importance of providing game designers with means to meet therapeutic requirements without being overloaded with medical details.

In order to meet these requirements, an adaptive approach could be useful in the early stages of the therapeutic game design. We focus in this paper on the dynamic difficulty adjustment of therapeutic tasks that takes into account the patient's abilities, motivation and training needs. In addition, the proposed approach allows building low cost theragames without the necessity of having a prior knowledge about the medical details.

3. RELATED WORK

We can find in the literature different works that deal with post-stroke rehabilitation based on a serious gaming strategy.

For instance, Heuser et al [7] suggest five therapeutic gaming exercises aiming to train impaired hand movements based on reaching and grasping targets. The adaptation technique consists in providing real-time feedbacks to the patients. Each difficulty level differs from the others by changing the color, speed and the size of virtual objects.

Furthermore, Chen Y. et al [2] propose a framework for media adaptation in task-oriented neuromotor rehabilitation based on biofeedback [9]. This technique is based on the adaptation of players' feedback according to their performances. Scenery images and their clarity, sounds variety and music instruments are used to reflect the arm movement. The adaptation technique depends on the choice of the musical instrument, the variation in tempo and the task difficulty, which is annotated by the therapist. Like the previous work, the difficulty level is designed in a static manner. This can lead to a situation in which the patient is confronted with continuous failure when the task is too difficult or continuous boredom when it is too easy. Both situations can decrease motivation to continue the therapy.

Ma et al, [11] propose an adaptive post-stroke rehabilitation system based on a virtual reality game. This therapeutic game aims to improve (i) functional arm capabilities, (ii) visual discrimination and (iii) selective attention using three difficulty levels: beginner, intermediate and expert. The dynamic adjustment of the system focuses on an in-game difficulty adaptation based on patient's progress. This is used to select tasks and configure the initial difficulty level of the game. Actually, the system suggests a difficulty level to the patient according to her/his model. This model includes mainly information about the patient's motor skills by using metrics such as the standard medical motricity index [4]. The adaptation technique is based on a specification matrix that determines the relationship between the patient's profile parameters and the difficulty levels.

Another interesting example of dynamic difficulty adaptation is proposed by Cameirao et al [1]. The authors propose a personalized training module based on a rehabilitation scenario, the so-called Spheroids. The adaptation consists in providing an appropriate task difficulty by capturing specific features of the movements of the arm. The adaptation technique focuses on an assessment step which represents the system calibration. The player is asked to move her hands to numbered dots positioned at specific locations on the tabletop. In each trial, hand and target position is randomly defined by the system.

In the above presented work, the game difficulty is often annotated by therapists in the beginning of the therapy session. Thus, when the patient fails to continue to play when the game difficulty is beyond her/his capabilities, engagement in the therapy and motivation to continue decrease. In addition, we can mention the lack of techniques allowing the reusability of game elements in the game framework. This is important as it allows building low cost theragames, while introducing variability in therapeutic activities that can also improve patients' motivation.

4. PROPOSITION

This section describes the proposed adaptation technique that aims to meet both therapy and game design requirements. The overall difficulty adaptation process is presented in figure 1.

A virtual rehabilitation session based on therapeutic serious game may provide an appropriate and helpful environment for both patients and therapists. The serious game can be helpful as it consists of a training tool, which can be used during: (i) the first months of in-centre stroke rehabilitation and (ii) when patients return home to help them to remotely continue their rehabilitation program in order to improve their quality of life.

Like in actual rehabilitation sessions, the game proposes tasks to the patient that allow her/him to perform movements in a 2D plan (a table) the so-called work plan. Due to the stroke, the patient finds it more or less difficult to reach certain regions of the work plan. In the experiment conduced, only pointing tasks, whereby the patient is asked to reach towards a target, are considered. Indeed, for post-stroke rehabilitation reaching represents an important part of upper-limb rehabilitation. When the patient is able to achieve pointing tasks, the therapists can focus on other types of tasks such grasping.

The first step of the adaptation process consists of collecting initial data of the patient's functional abilities. This allows constructing a model about patient's movement abilities on the work plan called "ability matrix".

The actual game needs information in order to adapt the difficulty of game tasks allowing movements towards certain regions of the work plan. In our adaptation model, this information is provided by a structure called "interaction matrix". The latter represents the work plan that is modelled by a matrix in which cells contain a Boolean value stating whether or not it is recommended to situate a target at this place.

The interaction matrix generator is defined by two parameters: the patient's ability matrix and a recommendation from the motivation module to either increase decrease or maintain the difficulty level of tasks.

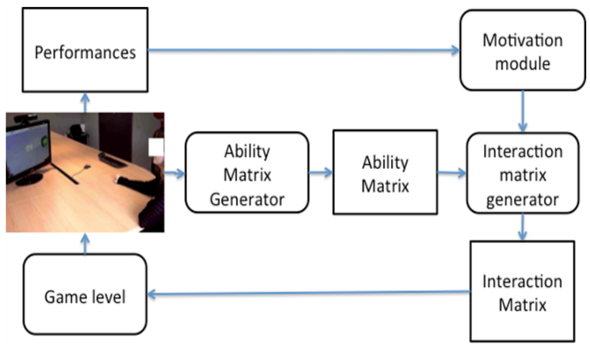

Figure 1: Overall process of dynamic difficulty adaptation

We describe in following sub-sections the dynamic difficulty adaptation components and their integration within a theragame application.

4.1 Player's Profile and the Abilities Assessment Step

In order to make decisions on the therapeutic objectives, therapists use generally clinical test scores, such as Fugl-Meyer score [15], or a kinematic based evaluation in virtual reality therapy. As for serious games, a kinematic based evaluation can be used and especially in our approach, the assessment step is included in the game. The game asks the player to reach for targets placed at different positions in the work plan. All information on execution of this initial task is stored in the patient's specific profile, alongside more general information like age, gender, dexterity, and impaired side, date of stroke, initial fugl-meyer score and neglect. The ability data is modelled by a structure so-called "ability zone". The player's profile is then used to choose the appropriate adaptation strategy according to the objective of the proposed game.

4.1.1 Ability Zone

Definition: An ability zone $A(m,n)$ is a matrix of a dimension $m \times n$ where m represents the number of rows and n the number of columns. Each cell $A[m,n] \in \mathbb{R}$ value represents an easiness score for the patient to reach the mapped area of the work plan.

The ability zone represents the patient's movement capabilities model within a 2D work plan. The goal of constructing such model is to build an instantaneous image of the patient's movement capabilities.

While the definition of the ability zone provides only its structure and intended semantics, it does not provide any means to construct this structure and different approaches can be used. For instance, in our previous work, a statistical approach is used in which each cell $A(i,j)$ contains a probability of success of the patient when asked to reach the mapped area [8].

In this paper, we suggest using a bio-inspired approach to build the ability zone using a virtual ant.

4.1.2 Digital-pheromone based algorithm

The ant algorithm was originally introduced by Dorigo [5] as a metaheuritic to solve problems that can be reduced to an optimal path finding when exploring a graph. The principle of this approach can be summarized as follows:

1. The tackled problem is modelled as a graph consisting of a set of nodes and links between these nodes.
2. Virtual ants are then introduced to explore nodes of the graph following links with the highest level of pheromones.
3. In fact, when exploring the graph, ants can deposit "pheromones" to indicate an interesting "finding". Following this behaviour, all interesting paths of the graph will be marked with high levels of pheromones and all other links will have low levels because pheromones are volatile.

In our context, the principles of ant algorithms are used to construct the patient's ability zone as follows:

1. A virtual ant is placed on the hand of the patient and follows its movements;
2. By moving her/his hand, the patient makes the ant explore the work plan;
3. The ant deposits pheromones following the movement path of the patient: the pheromones represent a signal that can be propagated to the work plan following a propagation law. Furthermore, the pheromone can also evaporate following an evaporation law. All areas that have been reached many times by patients are considered as easy and the others as difficult.

Propagation law:

The propagation law is an important feature since it allows predicting the difficulty of nearest cells without requiring the patient to actually explore them. The predicted difficulty is less important than the actual one and the pheromone signal has to be accordingly decreased. In our approach we focused on a linear propagation function. This function takes as parameter a range w (defined according to the wanted precision of the movement) and propagates the pheromone signal to all cells within the w-range of the current position. The level of the pheromone that reaches the cell, c, when the ant is located at cell, s, is calculated as follows:

$$level_s(c) = \begin{cases} \frac{-\varphi}{w}\ dist(s,c) + \varphi & \text{, if } dist(s,c) \leq w \\ 0, & \text{otherwise} \end{cases}$$

φ represents the initial (or nominal) level of the pheromone deposited at the location of the ant and $dist(s,c)$ indicates the distance between the cell c and the location of the ant s.

Evaporation law:

The evaporation law is as important as the propagation law since it allows forgetting regions that the patient has reached by chance. In fact, since the patient's movements are not totally controlled, the patient may reach involuntarily some areas of the work plan. The volatile nature of pheromones allows ignoring this information, which may disturb the decision making on difficulty. The memory of the evaporation law is defined by task parameters according to level of details chosen by the therapist.

Improving the method accuracy:

To be accurate, the proposed method has to take into account the movement as well as its goal. In fact, successful movements where the player reaches the target with "a good quality", have to be given more importance than unsuccessful movements where the player does not reach the target or reaches it with inaccurate and uncontrolled movement path. For this reason, the nominal pheromone signal deposited by the ant is modulated by a movement indicator that expresses its quality. Within the context of this study we have used the following model to modulate the level of the pheromone.

Knowing that the patient has reached the target moving along the path p, the pheromone model can be described as follow:

$$\varphi' = \varphi * \alpha(p), \text{where } \alpha(p) = \begin{cases} 1/velocity\_peaks(p) \\ 0, \quad\quad\quad\quad \text{otherwise} \end{cases}$$

This model is based on movement kinematic studies that link the accuracy of a movement path to the number of velocity peaks. The more velocity peaks a path contains, the less accurate it is (Oujamaa et al. 2009)

Example:

(a) (b)

Figure 2: Example of pheromones deposited by an ant following the patient's hand (a); the application of evaporation law reduces noises due to uncontrolled movements (b)

Figure 2 presents an example where the ant has followed patient's movements. Grey scales are used to indicate the different level of the pheromone (the light grey cells represent cells were successfully reached). As shown in (b) the volatile nature of pheromone helps reducing noises coming from uncontrolled movements. This image provides a simple indication of the patient's ability zone.

4.2 Dynamic difficulty adjustment technique

4.2.1 General framework

In [8] we have introduced a motivation model based on job satisfaction and activation theory to adapt task difficulty during rehabilitation sessions. In this approach motivation is considered as a regulation process (see figure 3). When the reality (outcome of a therapeutic game) is consistent with the expectations of the patient (perception of own motor skills) then this is considered as a stabilized satisfaction state. The patient attempts to provide effort to maintain this steady state. In the case of a minor disruption (constructive dissatisfaction), inducing challenge, the patient may produce efforts to regulate her/his satisfaction state. The difficulty adaptation process aims to produce a constructive dissatisfaction situation to keep the patient engaged in the therapy session, which can increase the rehabilitation volume (i.e total time and number of therapy session)

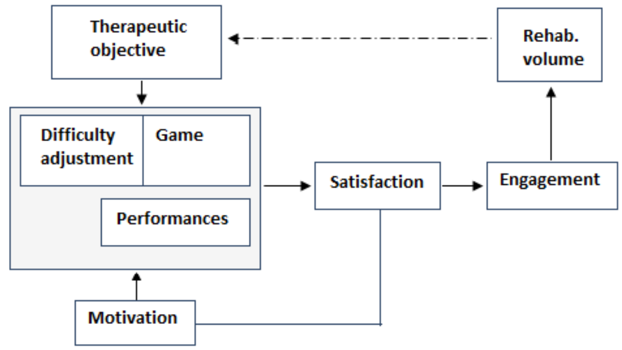

Figure 3: Example of pheromones deposited by an ant following the patient's hand (a); the application of evaporation law reduces noises due to uncontrolled movements (b)

Depending on successes or failures of the patient the motivation module provides one of the following recommendations:

- Decrease task difficulty: this happens when the player is confronted with a situation of consecutive failures; it is important to decrease difficulty level in order to avoid her/his frustration.
- Increase task difficulty: when the player is in a situation of consecutive successes and finds the game very easy, it is important to increase the difficulty to maintain her/his engagement and avoid boringness.
- Maintain the level task difficulty: the player is reaching a steady state that should be maintained.

In order to get more details about the motivation module to make these decisions see [8]

4.2.2 Interaction Matrix

Definition: An interaction matrix of a dimension $m \times n$ is defined as $I(m,n)$ where m represents the number of rows and n the number of columns. Each cell $I[m,n] \in \{0,1\}$ contains a binary value indicating whether or not an interaction with the player is desired within this cell.

The interaction matrix is a structure that models the 2D work plan used by patients to perform their rehabilitation tasks. Depending on the pointing device used (IR emitter, graphics tablet, mouse, Kinect) and the specific movement capability, the actual working area becomes more or less important. For this reason, the actual size of the work plan can be estimated to 1.5m width and 1.5m height.

The work plan is mapped to the action matrix by defining a scale used to translate each element (i,j) of the action matrix to a rectangular area defined by the following indices, left-bottom and right-top points: $(\mathrm{i} * \text{ cell\_height}, \mathrm{j} * \text{cell\_width})$

and $((\mathrm{i}+1) * \text{ cell\_heigh}, (\mathrm{j}+1) * \text{cell\_width})$

The interaction matrix can be used to either: (i) challenge the patient, (ii) support her/him or (iii) maintain the current state. The interaction matrix will influence positions of game objects in the virtual word.

Depending on the motivation module and the patient's ability matrix, the decision making on difficulty levels can influence the interaction matrices.

Case 1: Increase difficulty

When the motivation module suggests increasing the difficulty, the player is succeeding too easily, which may produce boringness and decreases her/his engagement. The goal is to explore more difficult cells. However, as said previously, it is important to create a constructive dissatisfaction without selecting very difficult areas of the work plan that are represented by the outside frontiers of the ability zone. In order to take this decision on difficulty, a simple gradient based algorithm is used, in which the gradient of each cell indicates direction of increase or decrease of the pheromone:

$$grad(A_{i,j}) = \sum\nolimits_{k,l \in i-1..i+1, j-1..j+1} (A_{i,j} - A_{k,l})$$

The interaction matrix is constructed by the following challenge function that simply keeps cells with negative gradient:

$$\text{Challenge}(X)_{i,j} = \begin{cases} 1, & grad(X_{i,j}) > 0 \\ 0, & \text{otherwise} \end{cases}$$

Case 2: Decrease difficulty

When the player is failing too often, as the exploration of the work plan is too large in regards to the player's current capabilities, the motivation module suggests decreasing the difficulty. The solution is then to come back to known areas where the player was succeeding. This can be established by selecting the inner frontier of the current ability zone.

In this case the interaction matrix is constructed by a support function that keeps cells with positive gradient:

$$\text{Support}(X)_{i,j} = \begin{cases} 1, & grad(X_{i,j}) < 0 \\ 0, & \text{otherwise} \end{cases}$$

Case 3: Maintain difficulty

In this case the motivation module recommends maintaining the current task's difficulty level. Consequently, the previous interaction matrix is maintained.

Example:

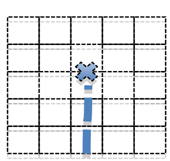

Figure 4: Example of a movement path.

Let suppose that a player has performed a movement path when she/he was asked to reach a target positioned at (3,3) (see Figure 5). When a virtual ant follows this path (with nominal pheromone level=1, diffusion parameter W=2 and evaporation=0.5) constructs the ability zone presented in Figure 5 (a).

(a)

0	0	0	0	0
0	0	0	0	0
0	0.5	1	0.5	0
0	1	1.5	1	0
0	1	1.5	1	0
0	0.5	0.5	0.5	0

(b)

0	0	0	0	0
1	1	1	1	1
1	0	0	0	1
1	0	0	0	1
1	0	0	0	1
1	0	1	0	1

(c)

0	0	0	0	0
0	0	0	0	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0
0	1	1	1	0

(a) Ability zone (b) Interaction matrix with negative gradients (c) Interaction matrix with positive gradients
Figure 5: matrices of example figure 4

In a challenging mode, the interaction matrix, which represents cells with negative gradients, is shown in figure 5 (b). In a supporting mode, the interaction matrix, which represents cells with positive gradients, is shown in figure 5 (c).

5. IMPLEMENTATION

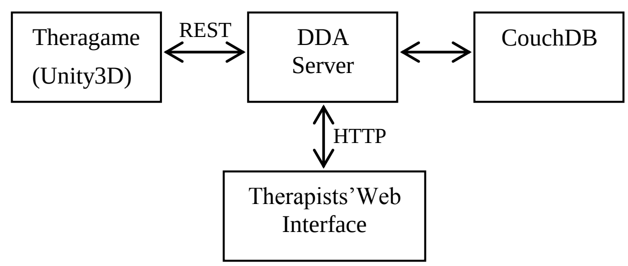

Figure 6: Technical architecture DDA server with the game.

The technical architecture used for integrating the adaptation mechanism through theragames is presented in Figure 6. The proposed game, used as a case study, has been developed using Unity3D. This game acts as a client and communicates with the dynamic difficulty adjustment (DDA) server using REST protocol. All information is stored using a NoSql server (CouchDb)

On one hand, the game traces patient's movement which allows the difficulty adjustment service to update the ability and interaction matrices. On the other hand, the interaction matrix is used by the theragame to determine targets' positions. In fact, they are placed as close as possible to recommended cells.

The DDA server makes it possible to play the theragame and dynamically adjust the difficulty of pointing tasks based on the observed patient's capabilities.

It is important to note that the game designer has no prior knowledge about therapy requirements. She or he has simply to take the recommendations of the interaction matrix into account, when building the scene of a game stage. These results represent a loose coupling between the therapeutic level and game level. Finally, the DDA server allows the therapist to access a set of monitoring services in order to consult patient's profile, performances and the evolution of its ability zone during the game session.

The presented approach is generic and can be applied to any point-and-click game (based on pointing tasks) adapted to stroke patients. The DDA server is accessible as an open source project (GPLv3) at http://gforge-lirmm.lirmm.fr/svn/mags/dda/

6. PILOT EXPERIMENT

6.1 Protocol and participants

To experiment with the presented approach we have executed a pilot study on healthy players. In fact, before testing on patients and disturb their classical rehabilitation program (planned for five weeks at least), it was necessary to experiment on healthy participants. Nonetheless, the experiment scheme with healthy players has to simulate difficulty of pointing tasks.

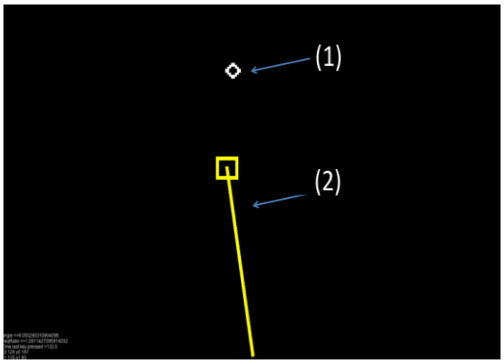

Figure 6: Screenshot of the pointing game used for the experiment

Figure 6 presents a screenshot of the game. The user controls a virtual rubber (2) To reach a target (1) she/he has to extend the rubber by continually hitting the space key on the keyboard using her/his non-dominant hand. More the frequency of hit is high, more the virtual rubber will extend; if the hit frequency diminishes then the rubber length diminishes to its minimal size. The mouse only provides the direction of the virtual rubber and is controlled by the dominant hand.

The experiment follows a repeated-measures design where each player plays with a random strategy of difficulty adaptation and our proposition for difficulty adaptation.

Figure 7: Assessment, the user is asked to erase as quickly as possible the screen by moving the rubber band

For all players the experiment was conducted in a similar way. An initial assessment allows collecting the maximum hit frequency of each user. The player then plays an assessment game by cleaning the screen using the virtual rubber. This builds the initial ability zone. Then, the player is asked to reach a sequence of targets in two sessions: session 'A' that uses a random algorithm and a session 'B' using our proposition to place the target. The order of these sessions has been alternated between players. The player was given a rest between these two sessions to avoid fatigue. Finally, the player reports on her/his own perceived difficulty, frustration and fatigue using the DP-15 scale [14] for both sessions A and B. It is worth noting that both sessions have the same duration of 2min.

The experimental group was composed by *n=10* participants with the following characteristics:

Table 1. Pilot experiment participants

Gender	Age	Dominant hand
7M 3F	(25.9 ± 4)	8 right; 2 left

We have introduced the following experimental hypotheses:

- I.H0 There is no difference between session A and session B concerning the success of pointing tasks
- II.H0 There is no difference between session A and session B concerning the level of perceived difficulty, frustration and fatigue.

6.2 Results

Results are reported as (Mean ± Standard Deviation). All statistical analyses were performed using R (http://www.r-project.org) version 2.12.0. A repeated measure t-test was used to reject hypothesizes.

IH0 was rejected since our proposition of difficulty adaptation has increased the number of successful pointing tasks by an average of M=4.3 with SD=3.5. The increase was statistically significant: $t(9)=3.85$, $p<0.01$ and r2=.97

II.H0 has not been rejected. This means that there is no statistically significant difference between session A and B concerning the perceived difficulty, frustration and fatigue.

6.3 Discussion

I.H0 hypothesis stating that there is no difference concerning the number of successful pointing tasks between session A and B has been rejected. We reason that the adaptation strategy has increased the number of successes by placing targets on the edge of the ability zone. It is important to note that tasks of session B have not been perceived as less difficult than tasks of session A by users. In fact, II.H0 shows that users have perceived no difference in difficulty of tasks between session A and B. This can be explained by the fact that the adaptation strategy places targets at the edge of ability zones maintaining consequently the challenge.
During qualitative interviews, all users have reported fatigue and frustration when controlling the virtual rubber by taping on the keyboard using the non-dominant member. This shows that the pointing task was challenging.

7. CONCLUSION

In this paper, we described a theragame framework aiming to meet both therapy and game requirements. The usefulness of such rehabilitation tool consists in providing a personalized and motivating rehabilitation session in which the training intensity and challenge are adapted to patient's abilities and training needs. We focused in this work on the adaptation of therapeutic game difficulty. The proposed difficulty adaptation technique is generic and dedicated to a family of therapeutic games for upper limb rehabilitation. The proposed technique is based on both the player's profile and her/his performances to dynamically adapt the game experience. In order to test the effectiveness of such approach we initially executed a pilot experiment on healthy players using a random strategy and the proposed adaptation strategy to place targets.

Results showed that the proposed adaptation strategy increased the total number of successful pointing tasks for the same amount of time, compared to a naive random algorithm.

Despite the large effect size of 79%, results of this experiment have to be carefully handled due to the small sample size (*n=10)* Further experiments with stroke patients have to be executed to confirm these initial findings.

8. REFERENCES

[1] Cameirao, M., Badia, S., Oller, E. and Verschure, P. 2010. Neurorehabilitation using the virtual reality based Rehabilitation Gaming System: methodology, design, psychometrics, usability and validation, *Journal of neuroengineering and rehabilitation*, BioMed Central Ltd.

[2] Chen, Y., Xu, W., Sundaram, H., Rikakis, T. and Liu, S. 2008. A dynamic decision network framework for online media adaptation in stroke rehabilitation, ACM Transactions on Multimedia Computing, Communications, and Applications (TOMCCAP), ACM, 1–38.

[3] Cirstea, M., and Levin, M. 2007. Improvement of arm movement patterns and endpoint control, Neurorehabilitation and Neural Repair.

[4] Demeurisse, G., Demol, and O., Robaya, E. 1980. *Motor evaluation in vascular hemiplegia, European Neurology* 19, 382–389.

[5] Dorigo. 2004. Ant Colony Optimization, Marco Dorigo and Thomas Stützle.

[6] Fitts .P.M. 1954. *The information capacity of the human motor system in controlling the amplitude of movement*. J Exp Psychol, 47:381-391.

[7] Heuser, A., Kourtev, H., Winter, S., Fensterheim, D., Burdea, G., Hentz, V. and Forducey, P.2006. Tele-Rehabilitation using the Rutgers Master II glove following Carpal Tunnel Release surgery, *In 2006 International Workshop on Virtual Rehabilitation*, IEEE publisher, 88-93.

[8] Hocine, N., and Gouaich, A. 2011. Therapeutic games' difficulty adaptation: An approach based on player's ability and motivation, In *proceedings of the IEEE International Conference on computer games, AI, animation mobile, multimedia, educational and serious games (CGAMES), 2011* . ISBN. 978-1-4577-1451-1, Louisville, KY, 257 - 261

[9] Huang, H. Chen, Y., Xu, W., Sundaram, H., Olson, L., Ingalls, T., Rikakis T., and He, J. 2006. Novel design of interactive multimodal biofeedback system for neurorehabilitation, Engineering in Medicine and Biology Society, EMBS'06. *28th Annual International Conference of the IEEE*, 4925–4928.

[10] Levin, M., Sveistrup, H., and Subramanian, S. 2010. Feedback and virtual environments for motor learning and rehabilitation, Schedae, 1, 19-36.

[11] Ma, M., Charles, D., McDonough, S., Crosbie, J., Oliver L. and McGoldrick C. 2007. Adaptive virtual reality games for rehabilitation of motor disorders, Uni-versal Access in Human-Computer Interaction, Ambient Interaction.

[12] Oujamaa, I. , Relave, J., Froger, D., Mottet and J. Pelissier 2009. Rehabilitation of arm function after stroke Literature review, Annals of physical and rehabilitation medicine.

[13] Popescu, V., Burdea, G., Girone, M., Bouzit, M. and Hentz, V. 2000. Orthopedic Telerehabilitation with Virtual Force Feedback,*Transactions on Information Technology in Biomedicine*, IEEE, 45–51.

[14] Deligneieres D.. La perception de la difficulte dans les taches motrices, HDR, Montpellier 1 University, 1996.

[15] Fugl-Meyer, AR., Jaasko, L., Leyman, I., Olsson, S. and Steglind, S. 1975. The post-stroke hemiplegic patient. 1. a method for evaluation of physical performance, *candinavian journal of rehabilitation medicine.*