DEVELOPMENT OF A VIRTUAL REALITY BASED PHYSICALLY INTERACTIVE GAME SYSTEM FOR VIRTUAL REHABILITATION WITH A CASE STUDY

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LEYLA SEZER

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DEVELOPMENT OF A VIRTUAL REALITY BASED PHYSICALLY INTERACTIVE GAME SYSTEM FOR VIRTUAL REHABILITATION WITH A CASE STUDY

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Approval of the Graduate School of Natural and Applied Sciences, Atılım University.

_____

Prof. Dr. Abdurrahim Özgenoğlu

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I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

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ABSTRACT

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The cost of Virtual Rehabilitation (VRH) in Turkey is very high. There are very limited centers that can afford to build such environments. Additionally, the patients are getting bored of regularly implementing the rehabilitation exercises, which decreases the level of improvement during the treatment.

This thesis develops a virtual reality (VR) game system to improve arm and hand motions of rehabilitation patients. The system is developed based on specific group of rehabilitation patients in Hacettepe University Physical Therapy and Rehabilitation center. The system also serves to the medical authorities, by creating reports about the performance of patients. In addition to this, doctors can also reach the statistical information about the patients and most importantly about the illness. The most important feature of the system is the improvement of patient's motion of arm and hand in a motivated way. Additionally, the low cost of the developed technology is pleased by many medical authorities.

Keywords: Virtual-Rehabilitation, Games for Health, Tele-Rehabilitation

ÖZ

SANAL GERÇEKLİK TEKNOLOJİSİ KULLANILARAK GELİŞTİRİLEN FİZİKSEL ETKİLEŞİMLİ OYUN SİSTEMİNİN SANAL REHABİLİTASYON TEDAVİSİ İÇİN KULLANILMASI: BİR DURUM ÇALIŞMASI

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Bu çalışmada fizik tedavi ve rehabilitasyon tedavisi gören hastalar ve doktorları için sanal-gerçeklik teknolojisi kullanılarak bir oyun sistemi geliştirilmiştir. Sistem beş farklı Fizik Tedavi ve Rehabilitasyon merkezinden toplanan bilgilerle belirli bir grup hastanın tedavisine uygun hareketleri içeren şekilde geliştirilmiştir. Hacettepe Üniversitesi Fizik Tedavi ve Rehabilitasyon Bölümündeki hastalar üzerinde uygulanmıştır. Bununla birlikte, oyunda zaman ve puan bilgisi tutulup ilgili doktora rapor edilmektedir. Bu sayede hastanın kontrolu yapılabilmektedir. Sonuçlar ele alındığında, hastalar üzerinde yadsınamaz bir gelişme görülmüştür. Sistemin en önemli özelliği hastanın oyun oynarken hiç sıkılmadan ve motivasyonu bozulmadan gerekli kaslarını geliştirip, tedavisinin daha kısa zamanda sonuç vermesini sağlamak olmuştur. Tüm bunlarla birlikte mali açıdan da oldukça uygun bir tedavi aracı olduğu gözlenmiştir.

Ana Kelimeler: Sanal rehabilitasyon, Sağlık İçin Oyunlar, tele-rehabilitasyon

To My Parents

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I would like to express my deepest appreciation to my supervisor Asst. Prof. Dr. Nergiz Ercil Çağıltay, for her guidance and feedbacks during the preparation of this thesis. It has been a great experience for me to work with her.

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TABLE OF CONTENTS

LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

LIST OF ABBREVIATIONS

VR	-	Virtual Reality
VRH	-	Virtual Rehabilitation
NR	-	Neuro- Rehabilitation

CHAPTER 1

INTRODUCTION

Many people in the society suffer from injuries and neuromuscular disorders which require physical rehabilitation exercises. These rehabilitation exercises need to be performed for a long period of time and require a regular routine. Because of the low motivation and morality and boredom, people who need to perform those activities, are usually not able to comply this routine. Therefore, as also Carvelho et al. declares, it is important to develop alternative methods of therapy and classical approaches for the treatment of these patients [1]. Games have been started to be used to treat many diseases for years [1]. Nowadays, some special games have been started to be used for many of the hospitals for the physical therapy. Games provide an alternative and higher motivated environment for people in every age group. Some hospitals have been established centers for their patients providing game-based rehabilitation activities. They use games which improve the hand, arm, leg, head and waist motions of the patients. Those games usually require a game console and they are developed for specific treatment requirements. However, setting those environments and maintaining those centers require a big effort and cost. Especially for the developing countries such as Turkey, it is not always possible to establish such centers. On the other hand, the patients need to stay in the hospital during the treatment (some times treatment takes months) which also increases the cost and effort of the treatment.

As an alternative approach, medical authorities move towards the computer game technology which provide eaiser to establish and maintain as well as cheaper solutions. This approach also provides a more portable and flexible settings for the rehabilitation by which the patient can use it at his/her bad, at home any time and anywhere that is more convenient for him/her.

Many studies have been established in this direction and then the term **Virtual-Rehabilitation (VRH)** is born. VRH was coined in 2002 by Professor Daniel Thalman of EPFL (Switzerland) and Professor Grigore Burdea of Rutgers University. In their view, the term applies to both physical therapy and cognitive interventions[1]. It offers numbers of advantages; it is entertaining, so motivating and can be performed by patient's home and monitored at a distance (becoming tele-rehabilitation) therefore the cost is cheaper.

Virtual Reality (VR) is an alternative computer based environment that simulates the real world with the combination of real and virtual world objects. Today VR technology has been used in several fields like education, entertainment, sport activities and scientific world to simulate variety of complex situations[1].

In this thesis, VR and VRH studies are drawn an attention to develop some solutions in Turkey as well. Accordingly, a prototype game system is developed for rehabilitation patients. After then, meetings was organized with five different rehabilitation centers to improve and developed system. The prototype of the system was presented to them. Medical authorities were very excited and interested in the topic and the game. Then a group of patients that the game may be helpfull was established and according to the requirements of this group, the game system was improved. One of the rehabilitation center was chosen to apply the game system to the patients, then the game was used in a period of time.

The results are very promising in that way medical authorities and patients said that, in traditional exercises patients do not make exercises more than 3 times a day, because patients do not like those exercises and they get bored. However, patients are playing the developed VR game a lot of time in a day without getting bored. The results show that some improvements have been gained in a shorter time period than the traditional exercises.

Moreover, doctors can control their patients easily, because the system reports critical informations about the patients. Moreover, doctors also reach the statistical information about patients and illness by using these reports.

Therefore, the system completely serves for the patients and the medical authorities. In addition to this, the cost for the technology is very cheap where the alternatives from abroad are very costly. Beacause of this high cost, currently in Turkey many hospitals are not be able to establish such centers.

Accordingly, in order to address the problems of rehabilitation centers, this study aims to develop a game for virtual rehabilitation of neuro-rehabilitation (NR) patients on arm, hand and hand wrist motions. It aims to provide anytime and anywhere rehabilitation approach for the patients while they are having fun by means of the developed game. The game also aims to help the doctors to monitor the progress of the patients and to adapt the game according to the specific exercises that the patient needs to be rehabilitated.

This thesis is organized as follows: Chapter 1 presents an introduction about the thesis, Chapter 2 covers the literature review for this study. Chapter 3 describes the methodolgy of this study. Next, Chapter 4 represents the developed game system and its tools in a detailed way. Chapter 5 reports the results obtained from the doctors and their patients after applying the game for the treatment. Finally, Chapter 6 provides an analysis of the results and mentions the future work for this study.

CHAPTER 2

BACKGROUND OF THE STUDY

In this chapter literature survey about the study is mentioned. The three approaches which are used for the VRH are explained. The comparison between all the systems are provided to have better view of the current approaches. Finally, the selected technology, web-cam is described in detail.

2.1 Rehabilitation

In general, the aim of rehabilitation is to increase the body functions of the patients, to help them to be indepedent in daily life activities and to improve their social contribution. Therefore, classical rehabiliation approaches contain therapical exercises and designed activities which is used for specific contiditions. In therapical exercises which are the most important period of rehabilitation, repetitive exercises was performed. In cronical patients, this treatment lasts longer than other patients'. Therefore, in a period of time patients started getting bored and active contribution decreased day by day. So the motivation of the patients was disappered[4].

Moreover, rehabilitation is a procedure of patients which must work with their physiotherapist. This kind of application increases the cost of rehabilitation services. To reduce the cost of rehabilitation services, to make more accessible to all these services and to make more patients reach for an physiotherapist, new methods or approaches have been developed. As all other health autrihorities,a physiotherapist also needs methods which are based on a proof and based on objective evaluations[3]. Therefore, treatment programs are made according to objective information.

From this view, applications which are based on objective virtual reality technologies are used for part of a treatment. These type of methods effects the patients treatment in a motivated way. So by using these methods, treatment can be more faster than traditional exercises.

2.2 Virtual Rehabilitation

Virtual Reality term combines the experience and perception of real world which is made by using computer technologies[2]. VR applications form real world sense for the people by using two and three dimensional animations. In addition to this, VR technologies make people interact with these real world objects. Virtual Reality can be seen in the areas from entertainment world to complicated scientific experiment. VR applications are mostly used for the education of anatomy, virtual surgery and rehabilitation field in the health area[2].

In the application of VR, people must accommodate the environment both physically and in the view of cognitive processes. From this aspect, "Virtual Rehabilition" term is born. In general, **Virtual Rehabilitation** is the treatment which is combined with the VR software and simulation tools[2]. In these treatments, patients can interact with the virtual environment by the help an object or by their hands. For example; A patient who can not walk independently in a street, can get a walk education in virtual environment.

Virtual Rehabilitation applications provide alternatives to the classical methods and provide different advantages. The most important advantage is the motivation; because, motivation is the most affected factor for treatment programs[5]. Motivation removes the fear, depression, inadaptable behavior and pessimism. These demeanors affect the recruitment negatively, besides in some cases they can stop the recruitment completely[5]. Computer games which are used for the treament, decrease the patients boring repetitions which are used in the classical rehabilitation technics. Patients make the iterative exercises in the games without being aware of the classical rehabilitation. They feel that, they are in a competition environment. Also patients can use the visual and audio feedbacks which are located in the game[7].

An alternative advantage of virtual rehabilitation is making the environment according to the patients preference. For example, by changing the speed of the game and changing the shape of objects, games can give different trainings to the different type of patients. The experience of real world applications are much more effective for the patients to adapt the daily life activities[8].

In the exercises of classical rehabilitation, patients and physiotherapists must work together. So the cost the treatment is very high in this type of treatments. In addition to this, in some regions of the Turkey, it is very difficult to find physiotherapists and equipments for all types of patients. In all of these cases, patients try to do their exercises without the help of any physiotherapists at their homes. Therefore, VRH programs give opportunities to the physical rehabilitation authorities to control their patients exercises[11].

By evaluating the improvement of the patients, VRH programs can be developed more efficiently. The main aim of these applications is to improve the rehabilitation patients daily life activities and at the same time to developed a rehabilitation tool with a very low cost.

2.3 VRH Studies in the Literatıure

In the world, VRH term is used in recent years and several applications were developed since 2002. There are three different VRH approaches which are beneficial for all types of rehabilitation patients. In this part, the three approaches are expressed.

1. Game-Based VRH

Nowadays, many hospitals have established game centers for their rehabilitation patients. These centers usually use some game environments which are developed to treat specific diseases (See Figure-1, Figure-2, Figure-3)[9]. For example; to improve arm motion a cycling game is used. The game is very similar with the games which is designed for childrens in a children's game lands. When the patients are playing

the game, they sense; they are driving a car and racing with the other cars in the game. Other examples of such games are Whack a Mole and Taico Drum Master games. In these games, main aim is to improve the arm functions of the patients. Objects are arised from blank spaces randomly, the patients try to put down all the objects by putting them with their gloves.

Figure-1 Cycling Game[9]

However, it is difficult to get benefits from these centers for the patients who can not walk. If there is any breakdown in the game environment, the repairing process is very costly and requires some time delays.

Figure-2 Whack a Mole Game[9]

Figure-3 Taico Drum Master Game[9]

2. Wii-Based VRH

In these systems, patient interacts with the system by moving the objects for getting support from the object [3]. The main features of the Wii Remote are its motion sensing capabilities that enable the clinician to measure end-point motion of the hand held controller and then, the patient's ability to manipulate the object (See also Figure-4) [3].

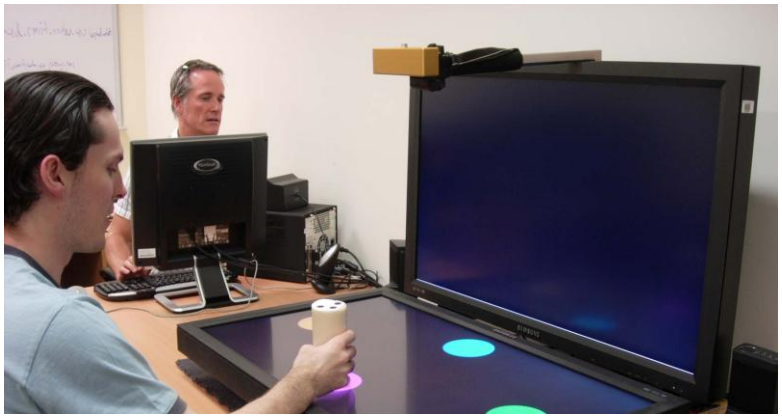

Figure-4 Elements workstation for upper limb assessment[3]

By using the Wii Remote systems the speed, precision, distance moved and target selection data can be recorded by the program. The program also allows monitoring performance of the users [3]. In this approach the motivated factor is also occurred for the rehabilitation patients. The usage of the system is very simple and the cost is also cheap. Researchers have found that patients who plays wii-based games, increase duration participating in therapy and are able to participate in dynamic

standing or sitting for longer periods of time [4]. Wii-Remote based is developed in the first studies of the VRH field. That help the patient by using an object play the game and make their exercises with a motivating factor. However, if the specific motion exercises need for the patient, that method can not be enough for the patients. For example; if the patients take hand knuckle improvement treatment, this game can only be used for the motivation factor and main activities improvement[4].

The Glenrose Rehabilitation Hospital is the first in North America to use the Wii technology to treat patients with movement and balance issues. Patients have progressed from their wheelchairs, unable to bend at the waist or pick up things from the floor, to stand and play in front of a TV screen, swinging a virtual golf stick, scoring a virtual bowling strike or knocking out an opponent in a boxing match[10] (See also Figure-5).

Figure-5 Albert Liaw plays his favourite boxing game on Wii after suffering a stroke due to a blow to the head during a boxing match[10]

Rehabilitation hospitals all over the world are purchasing Wii game systems to use as part of the physical therapy for their patients treatments. For example; strokes, accidents and combat injuries. Patients use the unique, motion-sensitive game controller to play games to build arm improvement and enhance their reflexes and hand-eye coordination [11].

While the Wii complements physical therapy, it will not replace traditional rehabilitation techniques, there is a sense that the Wii is going to be useful even though it was not specifically designed for rehabilitation. Medical authorities try to learn the system's possibilities as well as its limits [11].

3. Simulation-Based VRH

In recent years, VR technologies have begun to be used as an evaluation and treatment tool in rehabilitation. In simulation-based applications also VR technology is used.

This approach includes haptic gloves to perceive all knuckles of the body of a patient's hand, arm or leg which is needed. This type of systems is much more advanced than Wii-Remotes. Mostly these systems simulates the activities of daily livings, such as; driving cooking, cleaning, self-care and sports (See also Figure-6, Figure-7) [5].

Figure-6

Figure-7

Figure-6 , Figure-7 the player of the game is trying to reach objects on the shelves in the game of supermarket simulation[5].

These applications not only give an opportunity not only for active learning for participants but also encourage and motivate. In addition to this, there is the ability to objectively measure activities of patients in challenging with valid environments, while maintaining all other measurements (See also Table-1) [12].

Table-1 Attributes of the important Simulation-Based applications and related examples

Attributes	Examples
Safe and ecologically valid environments	1-Training patients with neglect to safely cross the street. 2-Assesment of driving with patients following traumatic brain injury.
Control over delivery of stimuli via adaptation of the environment and task to elicit various levels of performance	3- Adaptation of GX-VR system in terms of color, direction, speed and amount of stimulus.
Gradual changes in task complexity while changing extent of therapist intervention	4-Using video-based VR system with patients following spinal cord injury.
Increased standardization of assesment and treatment protocols	5-Assesment of cognitive function using a virtual kitchen.
Objective measurement of behaviour and performance	6-Documenting hand function (eg,range of motion of fingers) after stroke. 7-Analyzing behaviour (movements of body parts as well as success in virtual tasks) of children with ADHD. 8-Providing leisure oppurtunities using video-based VR with young adults with physical and intellectual disabilities.

To better implement the daily life activities, these simulations are mostly developed in a 3D environment. In most cases of our daily life activities, people use their hands; getting dressed, self-grooming, picking up and handling objects from food to books to toys. Patients who have problems with their hands need these types of simulations. For example; children with hemiplegia which has occurred after any injury in one side of the brain, have difficulty with the activities of daily living from the time they get up in the morning to the time they go to bed. By wearing a sensing glove to their hand, they can connect to the video game and are encouraged to improve their hand activities[6].

In traditional exercises, speed of the area which needs the therapy is also measured. Therefore, some of the games are developed by considering the speed factor as well. For example; in a game, there are butterflies which should be caught from the patients to get points, fly fast, this in turn requires faster reaction time from the patients (See also Figure-8, Figure-9, Figure-10) [6].

Davies et al. [12] developed three desktop applications for rehabilitation of daily tasks; a virtual kitchen, a service and vending machine and a hospital and university

way-finding enivironment. In all these applications, patients have chance to practice in an actual environment. From there, these researchers developed a "**tele-rehabilitation**" system for use at home under supervision by practitioners from a clinic, thus enabling training without having to travel which is difficult for many patients[12]. By changing the position of the web camera, this type of games can be applied to different part the bodies of patients. Some brain injuries affect the foot step of the patients, so a new game can be developed by new direction of a web-cam and this time the foot step motions and speed can be measured.

Figure-8

Figure-9

Figure-10

Figure-8, 9, 10 Game used for the gripping improvement for the all type of rehabilitation patients [12]

There are some examples of simulations and their explanations;

Street Crossing Using a Virtual Environment Mobility Simulator

The Rutgers mega-ankle robot was designed to simulate a walking application for the related patients. The platform compressed air for crossing patients to the street easily. Information about the patients are stored; avg speed, step count, etc. There are some vehicles which are moving across the street. In upper levels, vehicles speed are higher than lower levels, that is used for the patients who tries to walk fastly in order to cross the street safely (See also Figure-11) [13].

Virtual Reality Environments For Post-Stroke Arm Rehabilitation

In this system, A VE simulating elevator buttons were developed to improve the arm functions of the related patients. Originality and motivation are the most important remarkable attributes in this system. The system also measures the arm improvement and gives feedbacks (See also Figure-12, Figure-13) [14].

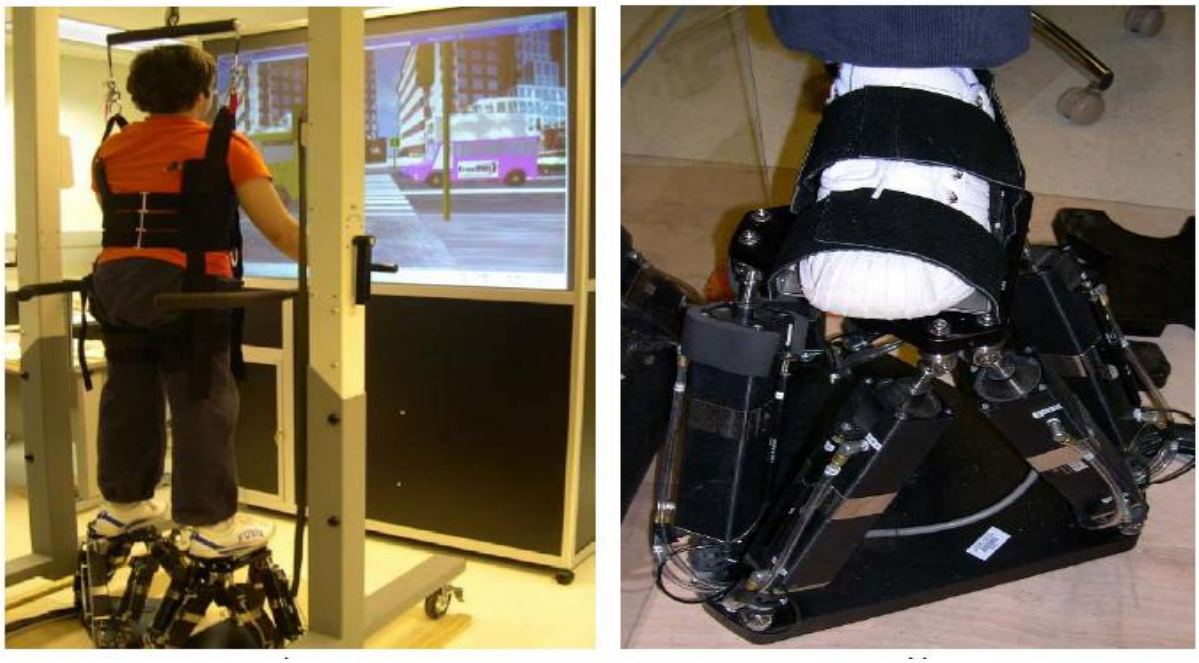

Figure-11 Walking simulation for the patients who loose the leg motions [13]

Figure-12

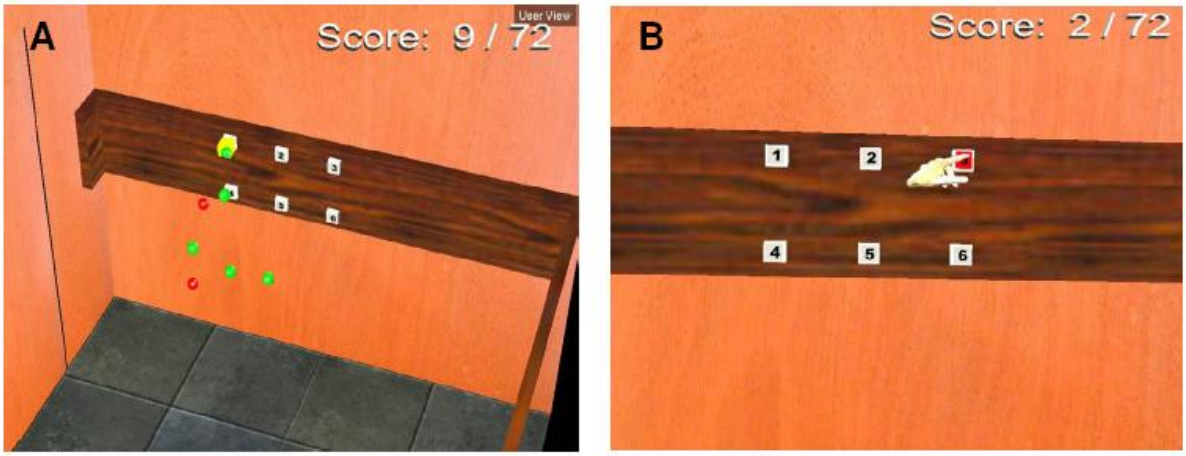

Figure-13

Figure-12, Figure-13 Simulation-based game to improve the arm, shoulder motion of the related patients [14].

The most important advantage of this type of game systems are that, all the specific motions; can be treated, because of the haptic gloves. These gloves include some specific tags for the specific areas. However, its motivated factor is less because in order to play the game patients should wear some additional apparatus. When they wear these extra units, their motivation can be affected because they think that all these units are taken because of their illnesses (the data is gathered from the interview with some patients in Rehabilitation Centers). Moreover, if the medical

authority wants to use a new game for new type of patients, it needs time to prepare a game for the patient. Because the coding is complex and requires specific development for the specific needs. Cost is very high in these immersive systems, financial limitations can be seen.

2.4 Problems and Limitations

In all three approaches there are some contributions and also limitations for the system. Table-2 shows a simple comprasion of these approaches.

Table-2 Comprasion of three approaches

Method	A	B	C
Cost	☹	😐	☹
Tele-rehabilitation	☹	😐	☹
Motivation	☺	☺	😐
Feedbacks to Doctors	😐	😐	☺
Complexity of composing system	☹	😐	☹

A: Game-Based VRH
B: Wii-Based VRH
C: Simulation-Based VRH

1- Cost

From the first aspect, the cost of the system application, varies in all approaches. In method A, Game-Based Rehabilitation, cost of the application is very high. All of the games are developed for special purposes, so the cost increases for this reason and also in a hospital, there are a lot of rehabilitation patients, for getting fair feedbacks, hospitals or rehabilitation centers need to buy many number of such games. So, number of the games changes from one hospital to another. Furthermore, if the number of games are not enough for the patients, they are forced to wait for a long time in a queue. Therefore, in this system large number of games need to be used, which increases the cost. In method B, Wii-Based Rehabilitation, cost is medium. Coding phase and application phase are not complex. Only cost is used for computer,

webcam and an object which used for getting motion. In method C, Simulation Based Rehabilitation, implementation cost is very high. In such systems, complex algorithms are used, so that makes the system cost very high. In addition to this, application is also elevated. To use the system correctly, an authorized person is needed for the guidance. That increases the cost of the system.

2 - Tele-Rehabilitation

The term means, the rehabilitation services can be applied over networks which used for the patients who want to continue their treatment at their homes. In the recent years, this idea is getting more popular. Hospitals, medical centers started to apply this new technology to their patients.

In method A, the adaption of the system to tele-rehabilitation is impossible, all the games are in real environment not in computer environment. Accordingly, it is impossible to share these games in a network. The method B, Wii- Based Rehabilitation, is suitable for tele-rehabilitation. However, only the controlling units are required, which can be provided by the medical center. If medical center can not provide that apparatus, this situation can be a problem for the patients. Finally method C, the problem of extra units is leap out extremely. In Simulation-Based system, tele rehabilitation is difficult. Because there are a lot of extra units and connections which are important for the system to be functional. All the units should be supplied by the rehabilitation center. During the implementation if any connection break down occurs at the patients home, hospital authorities need to help patient which is costly and make it complicated for the tele-rehabilition technology.

3 - Motivation Factor

Methods A and B, offers high motivated environment applicable for the rehabilitation patients. In these two systems, patients only focus to the game and make hidden exercises in the game. In method C, although the system features are very high qualified and simulation are extremely similar to the real life, motivation factor is less than other methods, because wearing lots of haptic gloves and all the connection cables disturb the patients. They feel their illness while they are playing.

So, while patients are playing the game which is developed by using method C, they get bored like in traditional exercises.

4 - FeedBacks To Doctors

In Game-Based systems, medical authorization must trace the scores of the patients at the end of the games. In some cases, they can be busy and they can not get the related scores. So it is very difficult from time to time provide feedbacks for the doctors in this system. Doctors can get feedbacks in a while of time. In Wii-Based systems, getting score phases are same, but differently from method A, a module can be inserted for the doctors which gets the scores and send the doctors. In third method, because of the usage of extra units and because of all extra units get the motion specific areas, time to time feedbacks can be taken easily and effectively.

5 - Complexity of the Composing System

In method A, there is a production process and a product. Product is complex because all the games includes hidden exercises which requires special production and also maintenance process. Accordingly, the composing complexity is high. In method B, system coding phase do not require as efford as in method A. The connection of Wii to the system is not a complex process. And among the other method, maintenance is an inevitable phase of all systems. It can be said that composing complexity of method B is medium. Finally, in method C, coding phase of the system is very difficult. Connections of the apparatus with the system are also extremely hard. In addition to this, the maintenance of the system can generate problems for the system developers. As a result, it has the highest cost for composing system efficiently.

2.5 Web-Cam Approach

Web-Cam approach can be called as mix-reality. In that environment only a web cam game, a computer and a web-cam are needed. Mostly, the games which are developed by using this technique are 2D and 3D applications. This approach is mostly used for the upper-limb rehabilitations [8]. Because these systems are not complex and the number of web-cams which are embedded to the system not much.

For the applications of other body motions, lots of camera needed. There are mostly used in Simulation-Based applications.

Moreover, in Web-Cam approach, no any extra units, extra apparatus and cable for connection is needed. There are only computer, web-cam and a patient to play the game. Patients can interact directly with their hands to the game. Video capturing algorithms are used for the games, because of this feature, lots of games can be created easily for the patients. Therefore, all these features separate this technique from the other types of virtual rehabilitation therapy approaches. In addition to this, the technique not only used for the rehabilitation patients, also it can be used for obesity treatment for children and development of children's bodies (See also Figure-14)[8]. Patients can be sensed that, they are the part of the game with real appeareances. Therefore, motivation is very high in these type of games. The game can be played in everywhere. These games are capable to be improved for the major activities of the patients.

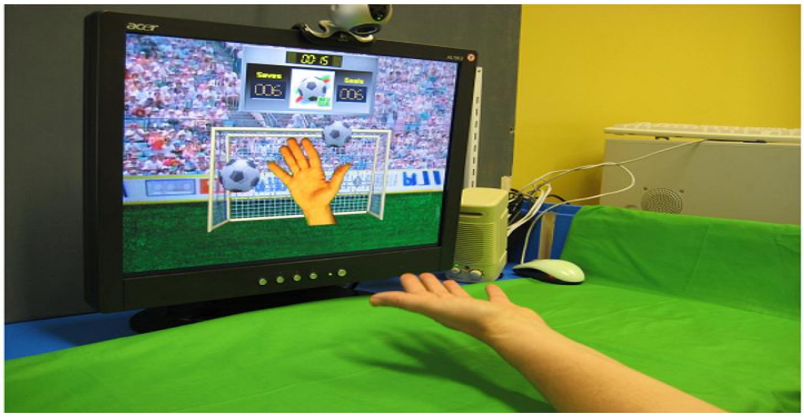

Figure-14 Web cam game to improve the hand motion of child patients [8]

By using this technology, tele-rehabilitation can be applied easily and provides feedbacks about the process of the patients that can be directly taken from the computer system and reported to the authorizations.

2.5.1 Why Web-Cam Approach

Together with the study group of Physical Therapy and Rehabilitation Center, all the approaches above are evaluated. By the idea of 5 critical factors which are Cost, Tele-Rehabilitation, Motivation Factor, Feedback to Doctors and Complexity of the System, web-cam approach is found to be the most suitable one for their patients.

- ✓ Firstly, the cost of the system application is very low when it is compare with the other 3 approaches. Additionally, code complexity and algorithms which are used in the system are medium level. Application of the system to the hospital or medical center is again cheaper and easier according to the other approaches. Only cost is the computer and the game development cost. Full system is embedded in the computer.

- ✓ In addition to this, motivation factor is also very high. Patients only play the game: there are not any other extra units for wearing. Therefore, patients easily forget their illness and they focus to the game.

- ✓ Feedback process in this system can easily applied. The score information and the other behaviors of the patient can be stored and sent to the related doctor with time information. In this study there is a system which gets all the score informations in all levels, and sends them to the doctors with an understandable reporting format.

- ✓ By the thought of the complexity of the composing system, the algorithms which are used in this system are medium level and clever. The algorithm can be applyied to lots of different patients needed. So, that increases the flexibility of the system.

- ✓ Moreover, the system is very flexible for the unlimited type of rehabilitation patients. The game system is developed for mostly NR patients. In the study, perception of the neuro-rehabilitation patients are measured with the motion of the their hand, arm and wrist improvements.

All the features encourage to develop and embed the new module. In that module, doctors and physiotherapists usage come forward. Firstly, the developed game

contains 8 different levels which are explained in a detailed in Chapter 4 - Development. All levels in the game are developed to improve different areas of patients, for example in first levels, patients should use their hand wrist, by playing the game, especially to increase the score. In other levels, game is implemented for the selectivity improvement. That is, there are lots of different colored balls and patients must select specific colored ball from the other balls and try to put the basket. In some levels, game improve the arm function of the patients. There are hidden traditional exercises for the patients. And finally, in the higher levels images are smaller than other levels and speed is increased to move the arm and hand wrist fastly. Then, new module is, creating patients own game. According to the patients need, intended levels come together with the patients.

In detaily, there is a page for doctors to insert patient information that is stored in the database. Information are, Citizen id, Name Surname, Birth Date to calculate the age of patient, Doctor and Improvement area which is arm or hand wrist. Then first page leads the medical authority to second page, this is used for creating new game for patient. Doctors select the levels for the patient's situation and game is formed by selected levels. In all the levels there some critical scores, if the patients can not reach the intended score same levels come to the patients screen, otherwise new level is started. At the end of the game, the information is reported with an understandable format to patient and at the same time it is recorded on the database for doctors.

To create all these environment, for designing the levels, flash is used and for camera capturing actionscript is used. For the doctors part, PHP, MySQL database server are used. Tools are sending data with others to publish the game. For storing and evaluating information database part is studied.

To sum up, doctors are pleased with the system. Application of the game on the patients are still continue. Until now, feedbacks make the patients and doctors are happy.

CHAPTER 3

RESEARCH METHOD

Based on the studies found in the literature, web-cam approach was chosen to develop a game system for the rehabilitation field. By the help of five different Physical Treatment and Rehabilitation Centers (these are; Hacettepe University Physical Therapy and Rehabilitation Center, Guven Hospital Physical Therapy and Rehabilitation Center, Fizyomed Rehabilitation Center, Maya Rehabilitation Center for Children and Finally TSK Physical Therapy and Rehabilitation Center), the game was developed and improved according to their requirements. The medical authorities in the department were excited about the topic and contributed the development accordingly. In Turkey, VR based studies are mostly used in education and in simulation-based science projects. In the area of VRH there are not many studies. Accordingly, this study aims to support the virtual rehabilitation better by using this new technology.

In this study both quantitative and qualitative data collection methods have been used. The research procedure can be shown in five main titles below.

1. Requirements Collection
2. Game Development
3. Game Demo and Rehabilitation Executives Attitude test on VRH and test on their patients.
4. Interviews with Rehabilitation Executives and Patients
5. Game Application

1. Requirements Collection

The game of this study is developed according to the requirements of the rehabilitation centers. After the game system is developed, a questionnaire (See also Appendix A) is prepared to better understand the attitudes of the rehabilitation executives. The questionnaire has been applied to the rehabilitation executives working in five different rehabilitation centers. In this study, to get relevant and efficient data about the subject, interviews are made. The questionnaire includes questions about;

- The rehabilitation exercises,
- Need of the patients and doctors,
- Virtual rehabilitation and web-cam game system.

2. Game Development

After the collecting of the requirements of the rehabilitation executives in periodical meetings, game is developed. Firstly, the specific group of patient is determined and exercises are chosen for the game. That is the patients who have the problems with their hand, hand wrist and arm motions. Then these types of exercises are all included into the game system. In chapter-4 game system is explained in a detailed way.

3. Game Demo and Rehabilitation Executives Attitude Test on VRH and Their Patients in Test VRH

As it mentioned in part 1, Appendix A contains the questionnaire for the doctors and the physical therapist. Game system is demonstrated in five different rehabilitation centers in Ankara. After the demonstration Twenty-three of doctors have filled the questionnaire. There is also questionnaire for the patients of some of these doctors. There are five patients who have filled the questionnaire about the patients (See also Appendix B). Results were collected and shown in the chapter 5.

4. Interviews With The Rehabilitation Executives

After collecting the questionnaires some specific interviews are made with the 7 of doctors (See also Appendix C) which are from these five rehabilitation centers. Interviews are recorded and transcribed for the results. That is also shown in the chapter 5 results part.

5. Game Application and Patient's Interview

The game is applied in the child patients of Hacettepe University Physical Therapy and Rehabilitation Center. There are 2 infant patients who play the game in three weeks. After getting the permission from their family, the application is made in the hospital by reflecting the game in a wall with the physical therapist of the patients. At the end of the application , interview is made with the patients , their opinions are mentioned in chapter 5. The doctor also observed the developed game application process and has reported her opinion on the process.

Observations

To get the objective results after applying the game system to the patients, 3 types of observations are used. First is the doctor observation, second is the system observation and finally the medical scale observation.

1. Doctor Observation

Doctors observation is the first method to control patients improvements. This method includes making basic daily life activities. For example; after the treatment doctors give a soft ball to their NR patients to grip it. If the patients have some difficulty by making this activity, treatment will continue in a while of time. There are other examples; for leg rehabilitation cycling acivity is given to the patients and also doctors control the patients leg improvement by using hold the leg in a while of time activity. (See also Figure-15, Figure-16, Figure-17). In addition to this, holding exercises are made by holding a cup of drink without spilling any of the drink. Like all these examples, doctors use daily life activities to measure the improvement of their patients.

Figure-15 Hand Rehabilitation

Figure-16 Leg Rehabilitation

Figure-17 Holding Leg Rehabilitation

2. System Observation

The second technic after applying the treatment is the system observation, that is the score and time information which are stored after the game into the database system. Information of a patients are stored after each game which is played by the patients. Date, time, level, and level score are used to measure the improvement of the patient.

3. Medical Scale Observation

That method is used at the end of all these two observations, it uses numerical values and graphics to measure the patient's improvements (See Figure-18, Figure-19).

Figure- 18 Hand Measurement

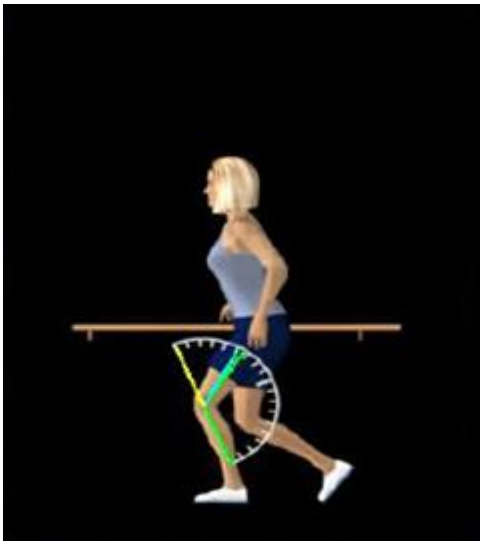

Figure-19 Leg Measurement

In this study, all these first two observations are used for neuro-rehabilitation patients and for their hand, hand wrist and arm improvement. To use the medical scale observation, six month applications are needed.

CHAPTER 4

DEVELOPMENT

In this chapter, development phase of the system is described in detail. Additionally, this chapter describes all requirement details of the developed system starting from the requirements collection and analysis.

4.1 System Requirements

In the development of this system rapid prototyping software development methodology has been applied. Accordingly, first a prototype game was developed to show the technology and abilities of the games that can be developed with this technology. Then the system is improved after the meeting with the 5 rehabilitation centers. All the meetings were very successfull. The prototype of the game was approved and admired from all the medical authorities, they told that the system can be improved to be beneficial for most of the rehabilitation patients. Some opinions after the interview of the 5 centers are summarized below;

- ✓ Need of a game for the shoulder improvement for the rehabilitation patients.
- ✓ Need of a game for the patients who breaks a body part.
- ✓ Need of a game for the leg and knee problems for the related patients.

Most of the doctors said that to get more benefits from the game, the game system should be applied first with the help of a physiotherapist. In addition to this, some medical centers said that because of the huge number of neurological (NR) problems in rehabilitation patients, game must be developed for the treatment of that kind of NR patients.

One of the Physical Therapy and Rehabilitation Center is chosen from 5 of them, then game was started to be developed for the NR patients who lost their hand, hand wrist and arm motions.

4.2 Overview Of The System

This first prototype of the game has been shared with the doctors of the Rehabilitation Center. The game was presented to them and they were very excited and interested in the topic with that game.

1-Target User Group

First of all, the patient group is determined as the ones who lost some functions of their bodies. The patients who lost full functionalities of their bodies were excluded from the group, since these patients need some special treatments. It is the NR patients who have the problems with their arms, hands and hand wrists. And then some ideas and contributions added by the help of medical authority and by the think of right motions. Then the game for improving arm and hand functionalities designed.

2-Game Objectives

During the game, the patient's view was monitored by using a web camera. In the game, colored balls falls into the environment from the left-side, right-side and up-to-down. The patients try to catch them by using their own hands and put the balls into the baskets which are located at the bottom of the game. Each ball which is put in a true colored basket gives 1 point score to the player. Finger, arm and hand muscle works by playing the game. Actually, there are different types of patients requiring different medication, so there are 8 levels in a game that uses different type of NR patients.

3- Game Story

In some cases of the therapy, the application of the game can be too heavy for some patients. So, doctors can manage a game by using only some levels of the game, not using full game. From there, first a page comes for the doctors or therapists. In that page, the doctors enter the information of a patient which are "Citizen Id", "Name

and Surname", "Date of Birth" to calculate the age of patients, "Area" which is arm or hand wrist and "The Doctor's Name" (See also Figure-20). All the information is stored into the database system. After all information are gathered, it is time for creating game for the patient. Doctor selects the suitable levels for the patient by using the next page, then the game system is created. In order to indicate the level's features there are some simple descriptions about the levels (See also Figure-21).

Figure-20

Figure-20 The doctors page to insert the patient information into the system.

Figure-21

Figure-21 The levels of the game and the levels to create a game for NR patients

When the game is coming the system asks the player camera allowance to capture the hand motion, players must approve this allowance. Then the game starts, “BAŞLAT” button sends the ball to the players screen. In the game all levels have different maximum scores. That score is used to jump to one upper level. If the patient could not get the maximum score, the game starts same level again by clicking the “LEVEL TEKRAR BAŞLAT” button, otherwise upper level is started by clicking the “LEVEL ATLA” button. If patients want to exit the game, they can choice the “OYUNDAN ÇIK” button. In this case, system reports the information of played game levels. In addition to this, last 1 minute, in all levels there is a message appears and it alerts the patient (See also Figure-22, Figure-23, Figure-24). All levels show the score information at the end of the game.

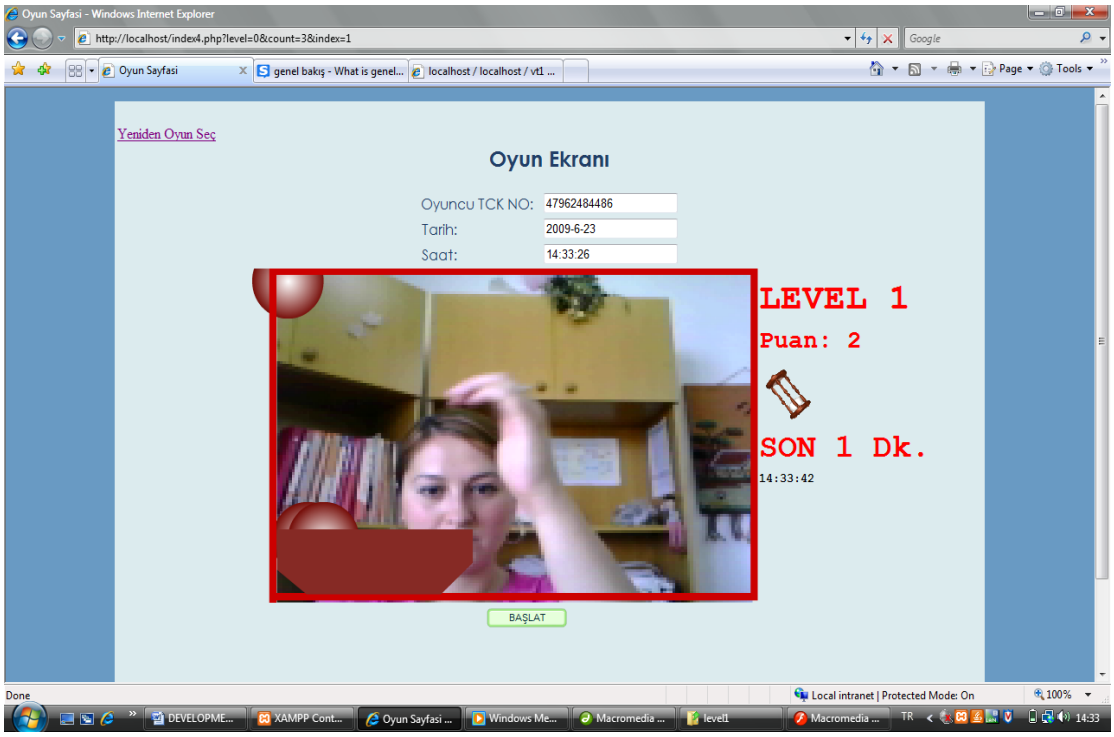

Figure-22

Figure-22 First level of the game system, the score information, time and the button which starts the balls falling operation

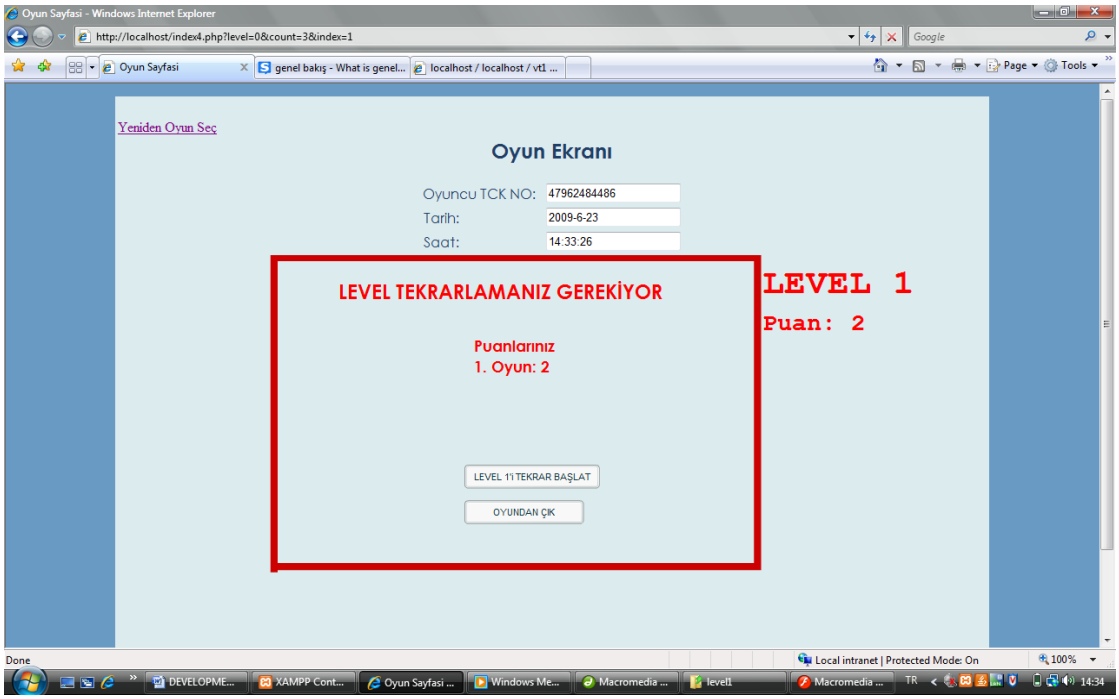

Figure- 23

Figure-23 Score information at the end of the game, if the player could not reach maximum score, the screen is shown in that figure.

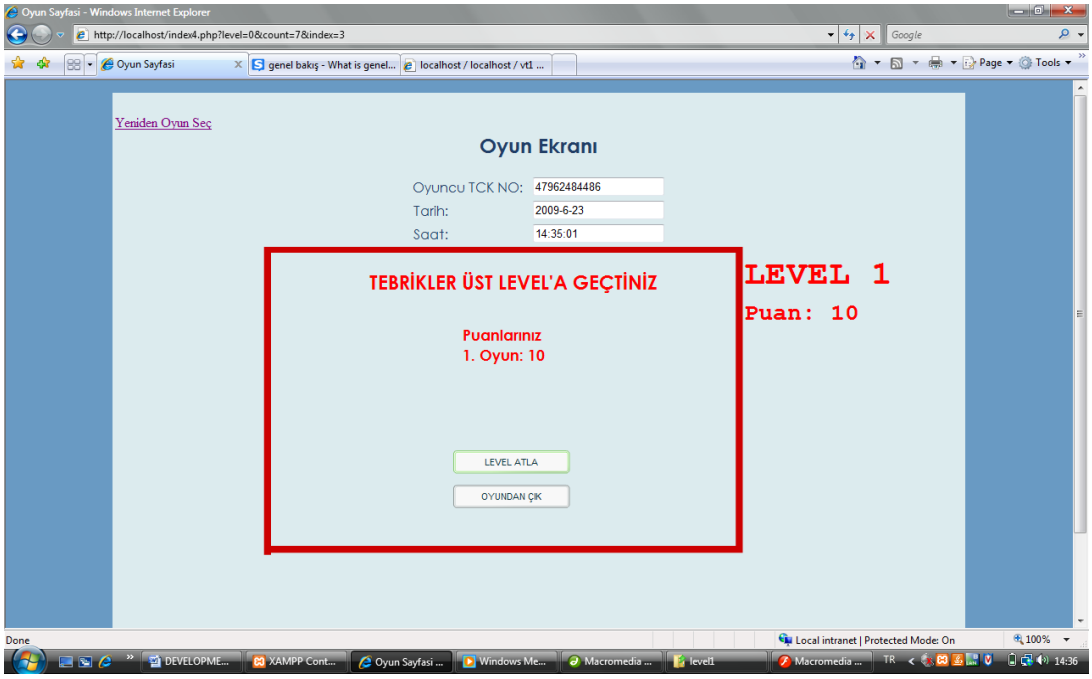

Figure-24

Figure-24 Score information at the end of the game, if the player could reach maximum score, the screen is shown in that figure.

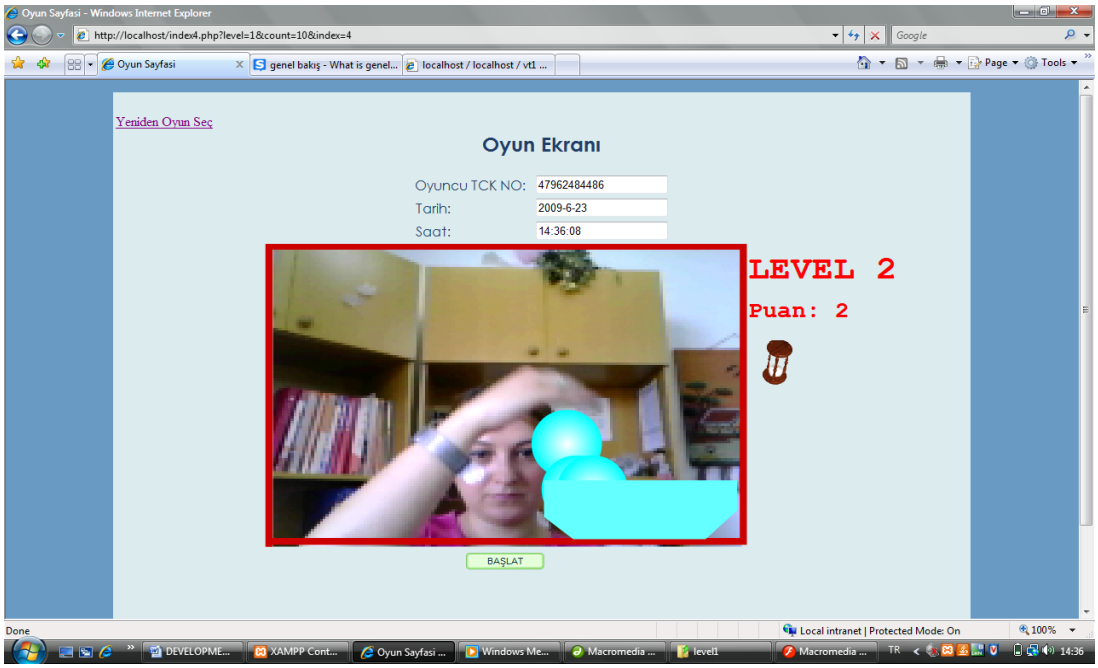

Figure-25

Figure-25 After the player gets the maximum score , new level comes as in the Figure-20 shows.

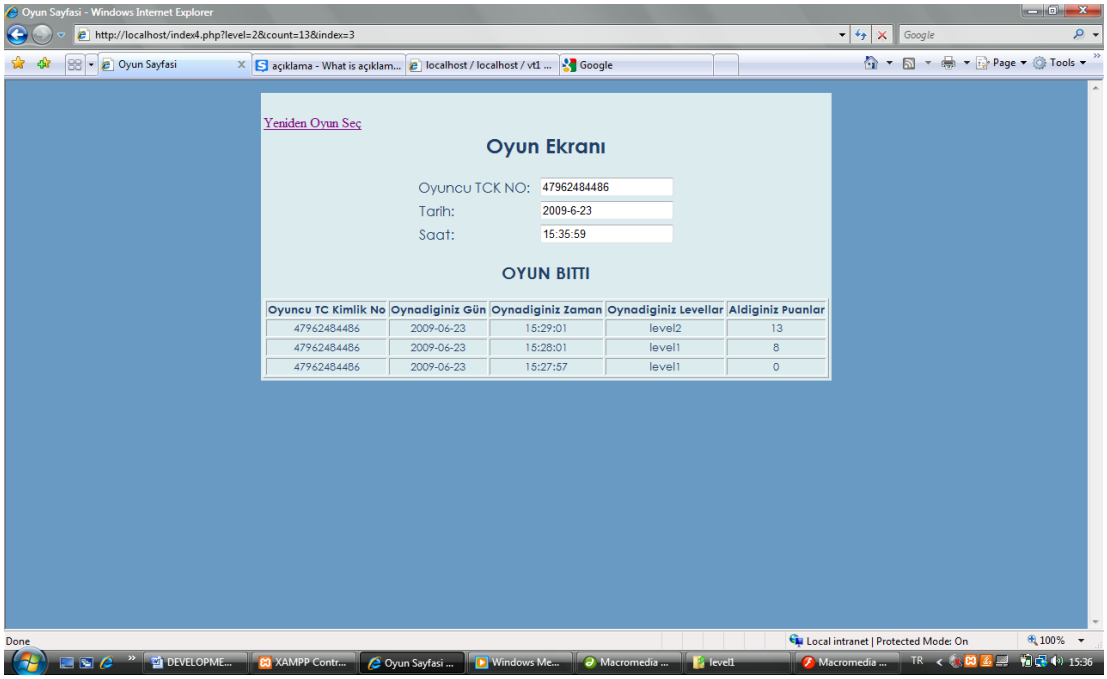

Figure-26

Figure-26 End of the game results about the player, brings the levels and level scores and also times which the levels are played.

After the player finishes the game, the information about the game is reported to the patient. If the patient plays the game at the medical center, doctor or physiotherapist deals with this report. All the information at the end of the game is inserted into the database automatically. So, medical authorities can see the improvement of patients and also they can reach the statiscal information about the all the patients (See also Figure-25, Figure-26). To the overview data flow diagram Figure-27 is ready.

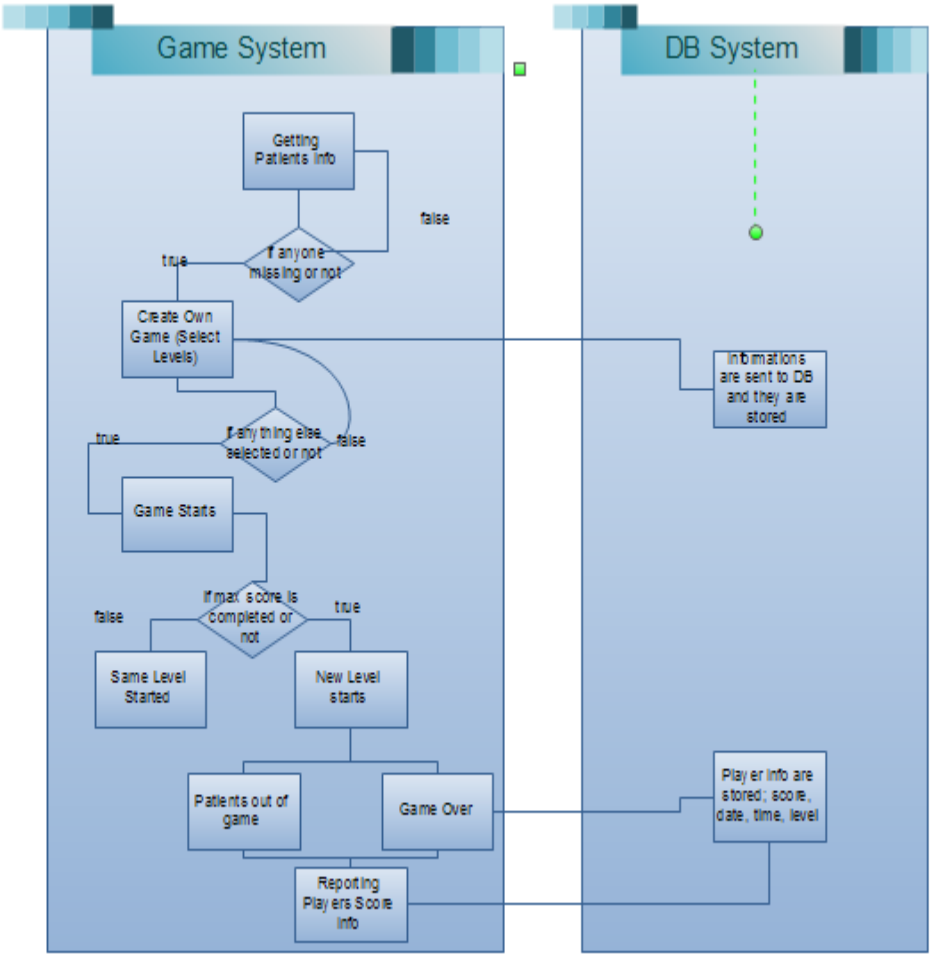

Figure-27 Data Flow diagram of the overview of the system

4 - How to Play

The game includes 8 levels and all levels include the colored balls which can fall from the upper right-side and upper left-side. Patients try to put the balls into the baskets that stay at the bottom of the game screen. If the patients can successfully put the balls into the basket, they get the points. Balls are falling down from the opposite direction of the basket.

In the first level of the game, balls are falling down only one-side of a game and speed is low for the patients who have heavy injuries or stroke. In first four levels, time is short; that is only two minutes. Moreover, in all levels of the game, last one minute game gives a warning for patients, which appears right side of the screen. In the levels of 4 and 5, there are different colored balls and they are falling in a random

direction. In these levels, major aim is to improve the motions of hand ankle of patients. And also these levels improve the sense of selectivity of patients who loses the perception of their abilities. In level 5, time is increased to 3 minutes. Levels of 6 and 7 the game are much faster than other levels. In that part, baskets are removed from bottom position to the right and left side of the game. The change of the baskets, provide the improvement of upper arm motions. In level 6, time is 3 minutes same as level 5; however in level 7, time is increased to the 4 minutes. Finally, level 8 includes same objects with a smaller size and the speed is also increased. Time is 4 minutes same as level 7.

The game can be used in the hospitals and rehabilitation centers or can be used at home of the patients, whenever it is needed. Furthermore, patients can play the game more than once and patients can see all their scores at the end of the game. At the end of the game patients can play the game again or they can go out of the game. All the levels are mentioned visually and detailed in the levels part.

Level 1

Level 1 contains the simple arm wrist exercises. There are only one red basket and only one red ball. Player tries to feel the ball to the basket by using his/her hands. When the player puts the ball, the direction of the ball will be changed. Then, it goes to the left direction. The basket is located at the left bottom of the page. The maximum score of level 1 is 8; if the player puts 8 balls inside the basket, next level will start. Otherwise, level 1 is played again. Therefore, player must use his/her hand wrist, the wrist should move left to right sides and also from up-to-down. The time of the level 1 is 2 minutes, actually this is the easiest easy level of the game. However, some heavy stroke patients can have difficulty while they are playing the level 1 (See also Figure-28).

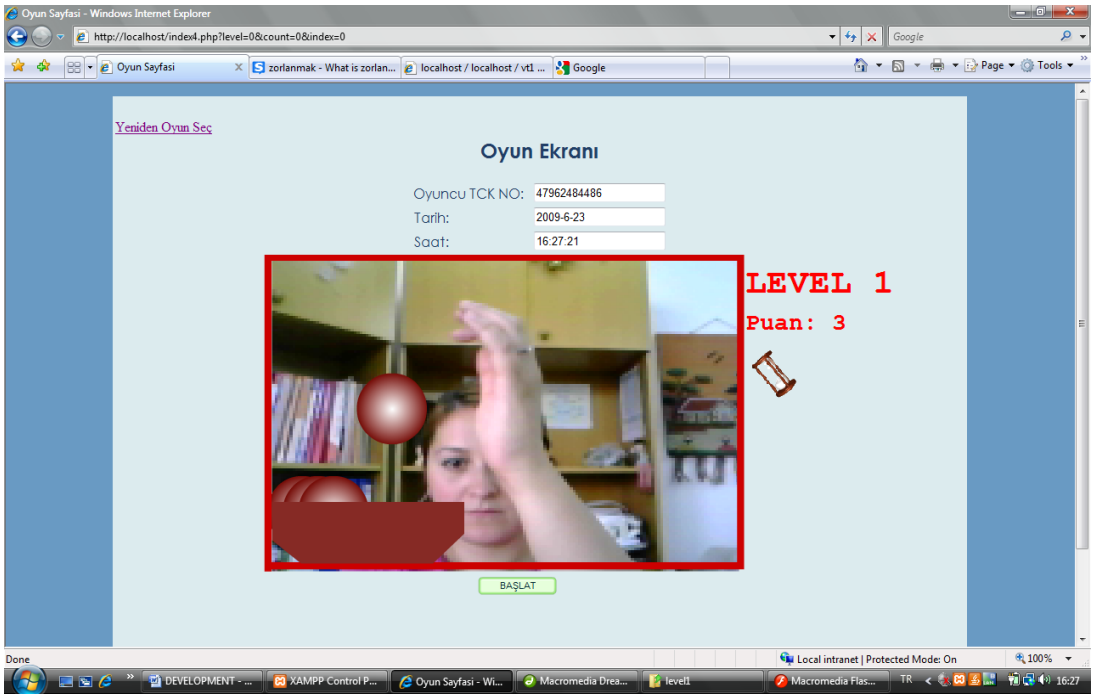

Figure-28 Level 1 of the game

Like, in all levels ,"BAŞLAT" button starts to fell the ball on the screen. At the end of the level, game displays the score of the player.

Level 2

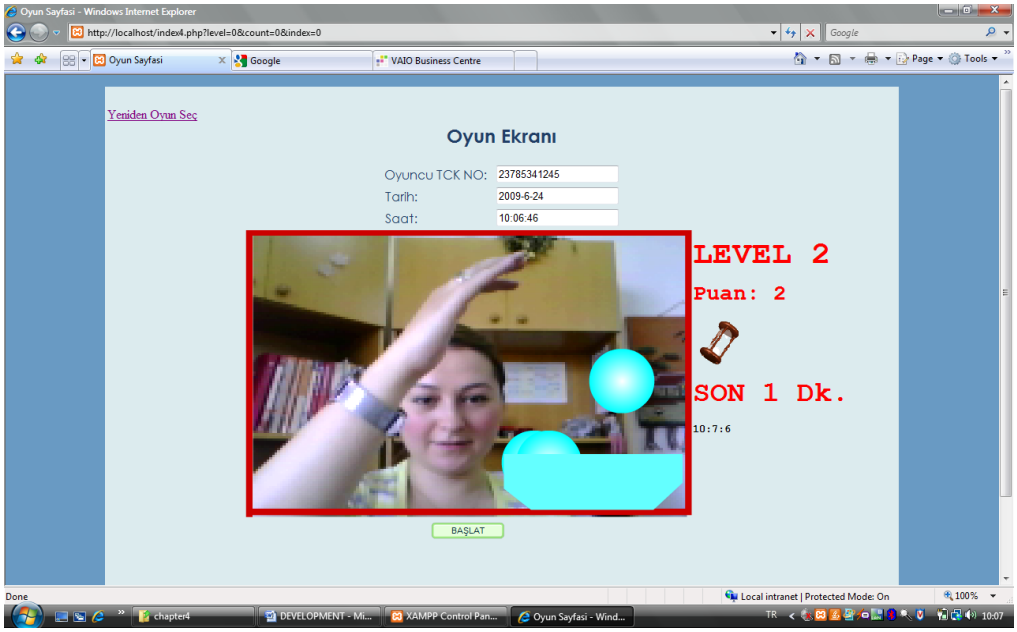

Figure-29 Level 2 of the game

In level2, the main aim is practicing the left hand, left arm and wrist motion. There are blue balls and a blue basket at the right side of the screen. Player tries to put the ball to inside of the basket. Similar to level 1, time is 2 minutes and maximum score is 7. If the player gets the score 7 and upper, next level can be played (See also Figure-29).

Level 3

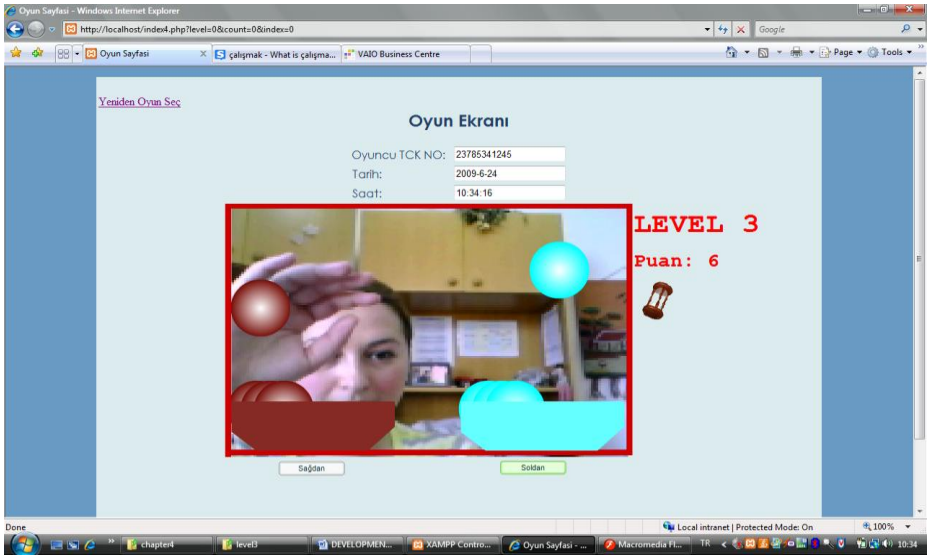

Figure-30 Level 3 of the game

In level 3, there are red and blue balls which are falling from left and right side of the screen. Like in previous levels, player tries to put the balls in to the same colored basket. Maximum score is 9 and time is 2 minutes. Different from previous levels, level 3 contains medium level right and left arm exercises and also left and right hand wrist improvements are aimed. In level 1 and 2 there are basic level exercises. However, in this level, player uses both hands, it increases the difficulty level (See also Figure-30).

Level 4

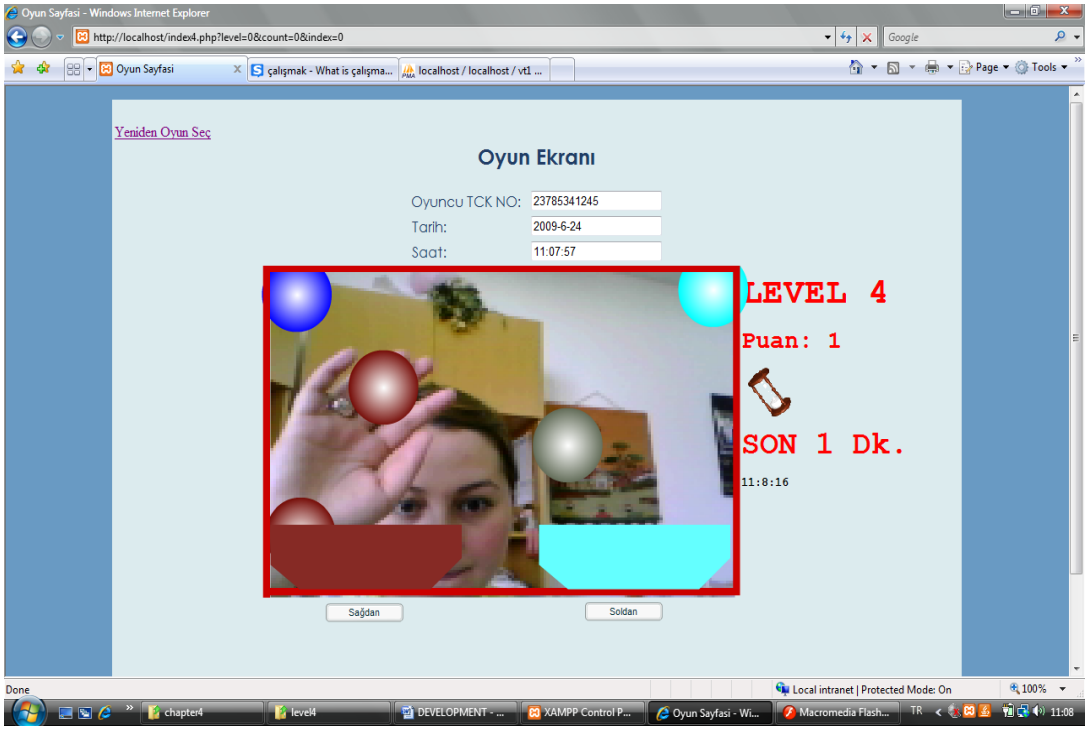

Figure-31 Level 4 of the game

After the overview of level 3, in level 4 there are 2 extra different colored balls to improve the perception of patients. The improvement of left and right arm and also left and right hand wrist are also added to the aims of the level 4. The maximum score and time is the same as level 3 which are 9 and 2 respectively (See also Figure-31). Player tries to select the red and blue balls from the others and put them inside the same colored baskets. Similar to the level 3 by clicking the "SAĞDAN" and "SOLDAN" buttons, balls are start falling down.

Level 5

Level 5 is very similar with the level4. There is only extra one pink ball, that means with the other balls, there are totally 3 balls. Speed is high, that is to make the level for the use of upper level hand wrist, and arm motions. Because of the speed increase, time is also increased (See Figure-32).

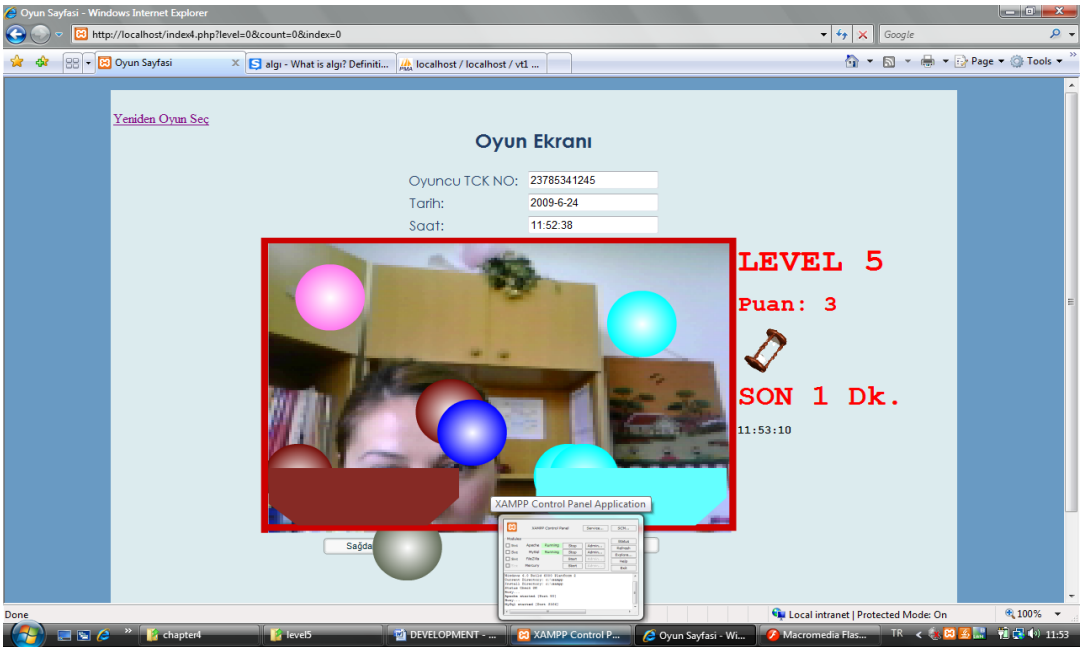

Figure-32 Level 5 of the game

Level 6

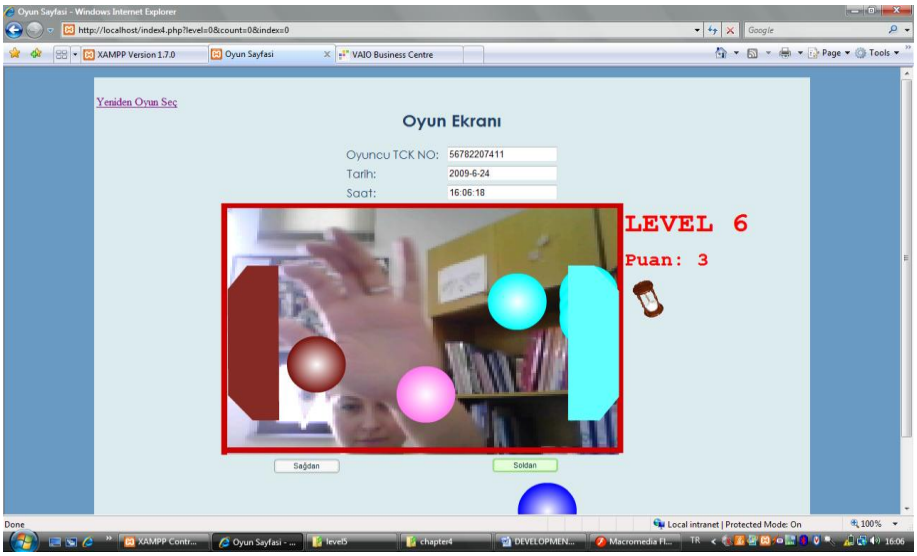

Figure-33 Level 6 of the game

Level 6 contains the medium level arm exercises. The position of the baskets are changed to the right and left side of the screen to improve the arm motions. There is also speed decreased, because it is difficult to put the balls by using new locations of the baskets. Time is 2 minutes and maximum score is 12 balls to go the next level.

Like level 5, there are extra 3 balls to measure the perception of NR patients (See also Figure-33).

Level 7

Unlike level6, in level 7 speed is increased, because it is appealed to the high level arm motions. Players hold out their hands, in order to catch the balls and put them into the same colored baskets. All other specifications are the same as the level 6; maximum score, basket locations, ball numbers and extra ball numbers (See also Figure-34).

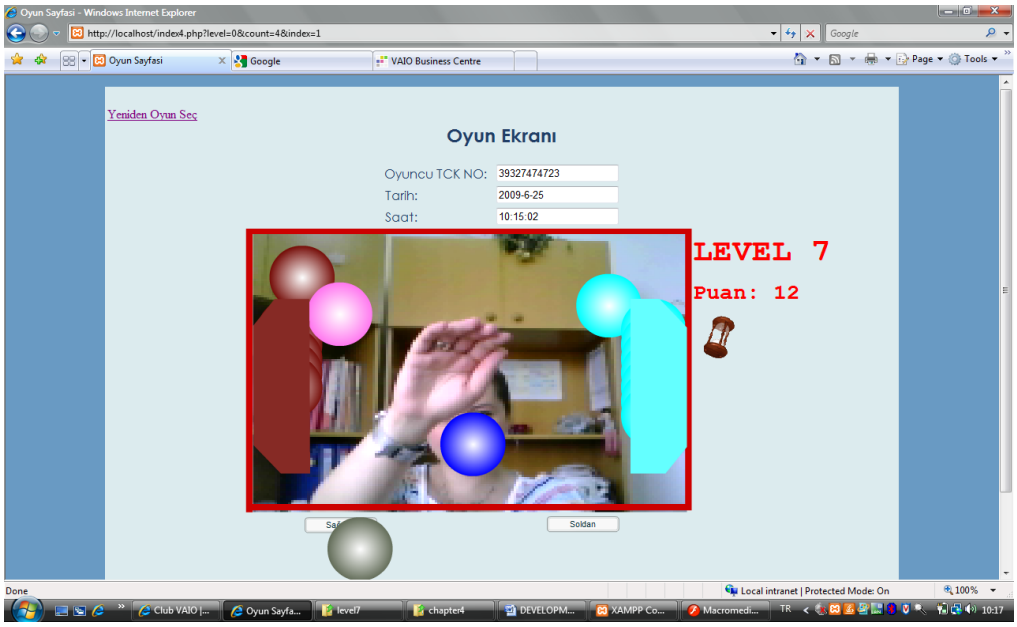

Figure-34 Level 7 of the game

Level 8

As seen in the Figure-35, in level 8, all the objects are minimized to make the level for upper level arm improvement. It is difficult to catch the balls in this level, because all of the balls are smaller than the other levels and speed is also high. Level 8 is very similar with the level 7; the maximum score, speed, extra balls to measure the perception are all the same as in the level 7.

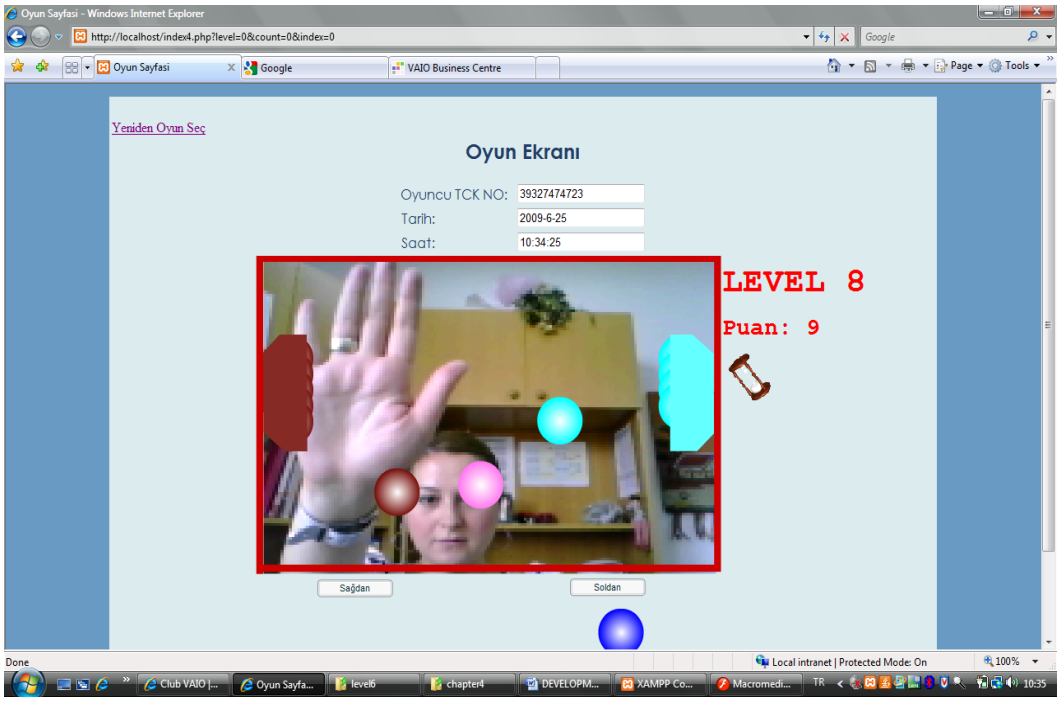

Figure-35 Level8 of the game

5 – Game Technologies

Flash 8 , action-script and Delphi programming languages are mostly used in this type of web cam games. In the coding phase of the game, there were some challenges. For example, it is difficult to capture the hand motion. In action-script part, the motion of the hand is perceived by the color of it. (Figure-36 show the overview of the full system)

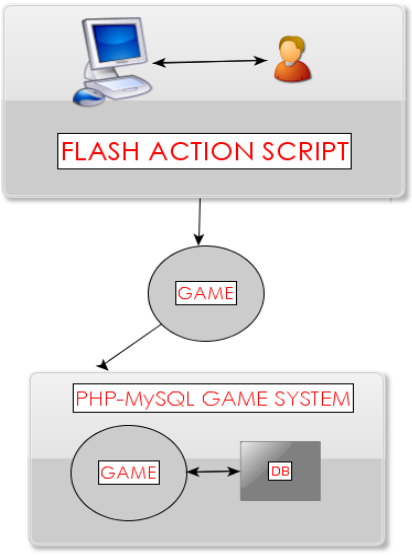

Figure-36 Overview of the system

In order to hold some information a DB was created as shown in Figure-37.

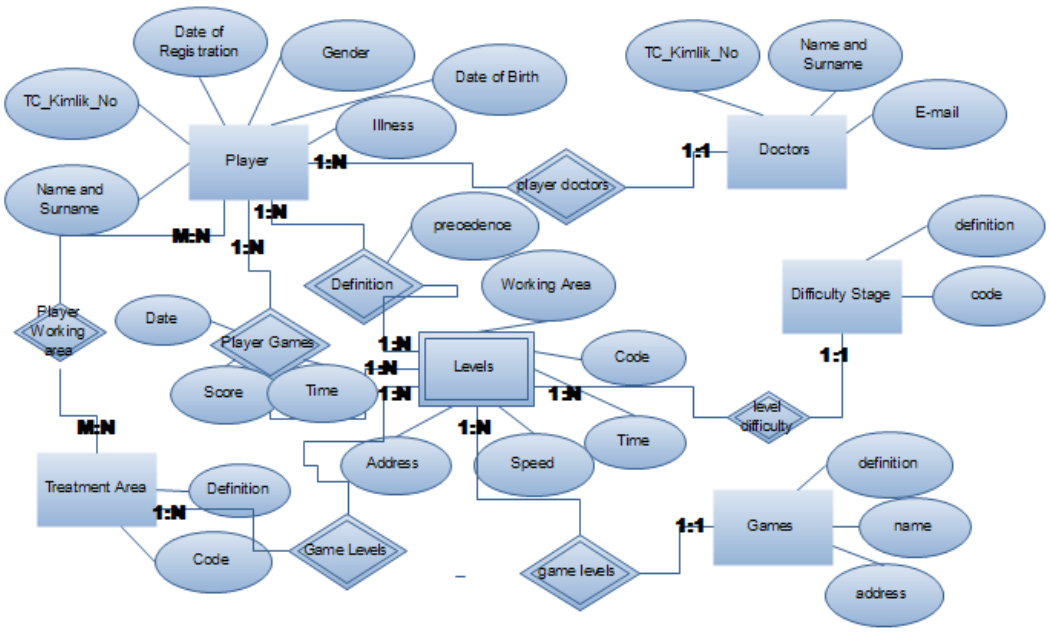

Figure-37 ER Diagram of the system

From that point, some aspect is occurred. By the help of the colored small tags, the grasping motion of hand fingers can be captured. According to that data, some specific motion controls can also be prepared in the web cam approach based virtual rehabilitation. The game now makes the arm, hand and hand wrist motion controls by using Flash 8, action-script 2.0 and it is applied to some of the patients. Implementation of the game is surviving according to the feedbacks of the patients and the doctors.

For the doctors part, PHP-MySQL tool is used. All pages are developed by using PHP. Flash game is embedded to the PHP page with the help of a script. However, the most difficult part of the game is creating patients' own game which is created from selected levels. In that part, selected levels are stored in an array and according to the array elements, PHP tool sends the flash which level must come, then the level is started.

After the end of the game to report the score, time, day information, Flash tool also send the variable to the PHP. In addition to this, all the data about a patient are stored in the database, to reach the statistical information about a patient and also illness.

CHAPTER 5

RESULTS

As it is mentioned in Chapter 3, the results of the questionnaires and interviews which were collected from patients and doctors will be explained in this part. Additionally, questions in the questionnaires are grouped and then visual results of the questions are shown. Then, the application of the some patients who used the system and the observations after the application will be mentioned.

The developed game is applied to the some rehabilitation patients in a rehabilitation center. Patients tried to catch the balls and put them into the baskets in all eight levels of the game. In some levels patients try to catch the balls by improving their hand ankle and in some other levels patients try to catch the balls by improving their upper arm motions. In some levels while patients try to catch balls, they enhanced their sense selectivity. If the balls can be put into the baskets; it adds 1 point to the score. Some of the patients had problems in their arm muscles, so by playing the game, they should raise their arm and give a motion to that area. On the other hand, some patients had a problem with their hands. They could not use their fingers smoothly. By playing the game they should catch the ball; by using their hands and put them into the baskets. The most effective part is that the patients react while playing the game with a smile in their faces, because it is enjoyable and very different from the traditional boring exercises. Therefore, doctors said that motivation is an inevitable part of all treatments. So in that field, it is also very significant. In traditional exercises, doctors give some objects to the patients to change their positions however patients make this therapy only twice a day. Doctors said that they must do that kind of exercises as much as possible. By playing games, they can make the exercises as many times as possible and whenever they want with an amusing way and also without feeling tired. Another complaint of the patients is that, while they are making

traditional exercises, they feel tired themselves, and then they do not want to continue doing exercises.

5.1 Rehabilitation Executives Attitude Test on VRH

From the first view, questionnaire includes 16 questions, 3 options are presented to the doctors to answer each questions. These are; " agree, no idea, disagree". However, in the interview part questions are asked to the doctors and answers are saved by using voice recorder. Then, all the answers are evaluated (See also Table-3).

Table 3 – Rehabilitation Executives Attitude Test on VRH and Results

Questions	Agree	No idea	Disagree
1. In the process of rehabilitation, hand, hand wrist and arm are the parts of the body which need treatment more occasionally.	**%75**	-	**%25**
2. In the process of the rehabilitation treatment mostly active and passive exercises are given to the patients	**%55**	-	**%45**
3. Active exercises are the most efficient ones which the patient can do their exercises by themshelves without any help of the physical therapist.	**%90**	-	**%10**
4. In passive and active exercises, many repetition needed to be performed which makes the patient to be bored.	**%100**	-	-
5. Games can be used, for the patients treatment.	**%100**	-	-
6. In the process rehabilitation, games can be used, for the active exercises.	**%100**	-	-
7. In the process rehabilitation, games can be used, for the passive exercises.	**%90**	-	**%10**
8. There can be lots of games for all the age group of the rehabilitation patients.	**%70**	-	**%30**
9. I know what is VRH games and I have used them.	**%25**	**%75**	-
10. Such games that you have shown are used in the Virtual Rehabilitation can be useful for the treatment of the rehabilitation patients.	**%75**	**%25**	-
11. Virtual Rehabilitation products are used in abroad, however purhasing cost of such products for Turkey is very high	**%75**	**%25**	-

Questions	Agree	No idea	Disagree
12. In Turkey, there are not many virtual rehabilitation games to be used by the rehabiliation centers.	**%70**	**%30**	-
13. For the treatment of the rehabilitation patients, I wold like to use such games.	**%100**	-	-
14. When such games which are used for the treatment of the patients, the motivation of the patient can be imposed positively.	**%100**	-	-
15. When such games is used for the treatment, the period of the treatment can be shortened.	**%100**	-	-
16. When such games used for the treatment, the cost can be reduced.	**%100**	-	-

5.1.1 Analysis of the Executives Test on VRH

In the first question, %75 of the medical authorities, agree with the rehabilitation patients mostly suffer from hand and arm motions. However, %25 of the medical authorities, said that patients also suffer from other fields of the their bodies. So, the study aims to improve the arm and hand motions. The game system includes 8 levels and all of them improved for the improvement of hand, hand wrist and arm motions.

In the second question, %55 of the authorities said that the mostly passive and active exercises are used for the treatment of the rehabilitation patients. On the other hand, %45 of the medical authorities said that, some of the rehabilitation patients can not raise their problematic area not in the least. These kind of exercises are only useful for the patients who lost some functios of their bodies. Therefore, the game system is also developed for the think of that situation.

In the third question, %90 of the medical authorities said that, patients who lost some part of the body motions, active exercises if the most effective exercises for the patients. However, %10 of them said that, in some conditions, patients must not move the problematic area, in the first phase of the treatment. So, from the think of that situation, active exercises are not useful for the first days of the treatment process. From that view, the game system will be used for most efficient phase of the all types of tye patients.

In the fourth question, iterative exercises can cause the motivation problem, that is reminded to the authorities. All of the doctors are agree with that points. In one of the center, one of the doctors gave an example about the subject. One of the exercises of the active exercises is holding the arm in a while of a time, to make this exercise, doctors said that to the patient get a paper and put it to the wall, without falling it put them in a while of time. This action is very important for arm motion improvement. However, lots of the patients can not make them more twice a day, because they get bored, and also it is irksome. From there, in the game system there lots of actions which patient must hold their hands and arm in a while of time to get the score.

In question 5, again all of the medical auhorities agree with the usage of the games for the treatment process. Actually it is, related with the question 4, to increase the motivation and to make the patients exercises periodically, it is an efficient idea. Moreover, in question 6, games can be used for the active exercises, is all approved from the doctors. Because, active exercises for the use shelf improvement, games are very suitable for that treatments.

In seventh question, % 90 of the doctors said that, games also can be used for the passive exercises. By the help of an medical authorities, game can be played. On the hand, %10 said that, it can be difficult for the heavily stroke patients. In question 8, it is asked that games can be used for all the age group of the patients. %70 of the executives are agree with the application of the game to all age groups. However, %30 of medical authorities are disagree with the subject. They think that, it needs suitable stage of education, so not all age group can be use this system. On the other hand, they complains about the child patients, in some age group it is difficult to apply the game system. That needs time to describe the game for some group of children. Therefore, in the game system, above the age of 7 children and the middle age group is choosen.

In question 9, after the answers are collected, it is disappointing %75 of the medical authorities have not any idea about the virtual rehabilitation and it is games. That shows that, in our country, doctors and physical therapists are still use traditional exercises. Very few number of rehabilitation centers use game technologies. However, these games are not virtual rehabilitation games, these are simple

rehabilitation games and some computer games. Therefore for the part a study, virtual rehabilitation technology is mentioned and some example games are shown to the doctors and physical therapists. Furthermore, %25 of authorithies deal with the virtual rehabilitation and it is games but they could not use the these technologies because of the cost.

For the question 10, %75 of medical authorities think that games which is developed for the virtual rehabilitation can be used for the all types of rehabilitation patients and also all age group of rehabilitation patients can be used these games. Moreover, %25 of the medical authorities do not sure about the topic, most of them hold an opinion about the topic for the first time. Some of them said that, it is also related with the game usage intsructions, if patients could not handle the intstructions, they can not play the game. They also append that, patients should have certain eductaional level to play the game and also to get the intended solutions. From this aspect, question 11 is answered, %75 of the people, are agreed about the low cost of development of virtual rehabilitation usage in our country, instead of buying technology from abroad. However, %25 of them have not any about the topic.

For the question 12, not only medical authorities answers are collected, but also observations are made 5 medical centers. One of the medical center which is the fully fledged rehabilitation center in the Turkey, gives two professors to help us and also for the study. Most the units are visited. In this center, there are digital system rooms, in these rooms some partial-virtual rehabilitation systems are used. In some units games are also applied for the patients. They also use lots of inventory for the traditional rehabilitation exercises. After the interview, they said that, virtual rehabilitation game systems are new technologies, they want to develop new projects about the subject. Because some exercises are made with the physical therapists, it can be applied in the computer which can gives more objective results than other methods. In other rehabilitation centers which are medium level centers according to the center that is mentioned above, traditional tools are used. Some of them use the some games for the patients. For example, in one center, the doctor displays a game that is sensible with the voice. Patients trying to clap with their hand and trying to make noise with their hand for getting higher scores. From there, % 70 of them, needs much more games, especially computer aided games, web cam games and

virtual rehabilitation games. %30 of them have no idea about the some rehabilitation centers working area and intended equipments.

In question 13, it is asked to the authorities, if they wants to use the low cost games system for their patients. They are fully agreed with the topic, this is a neccesity for them, it can be seen easily. Question 14, that is also related with the question 13, auhorities are all agreed wtih the motivation factor of these types of games. Motivation is the most critical issue for the patients. In a short time, most of the patients loose their motivations, to keep their motivation until the end of a treatment is imposibble for most cases. To increase the motivation and keep longer time than before, this type of games can be use. That is approved from all executives. Also related with the questions 13 and 14, question 15 asks about the time of treatment that can be shorten by using game. As it mentioned before, VRH games increase the motivation, it is proportional with time also, if the motivation high, treatment time is decrease. That is also agreed by all the doctors and physical therapists. Moreover, treatment cost can also decrease related with the time. That is the question16, and fully agreed by the executives.

5.2 Patients Test on VRH

Like doctor's questionnaire, patient questionnaire is also prepared. Actually, doctor's opinions are the most important part of the study. It is necessary for collecting objective and medical data, and also for developing efficient systems. However, patient's ideas about the game system, can be support the study. In this part, unlike doctor's questionnaire, there are 10 questions are asked to the patients to get the opinions of the patients (See also Table-4). Questions are about the difficulties and boring points in traditional exercises, periodical exercises, problematic areas of patients, opinions of patients about games and computer games.

Table 4 - Patient's Test on VRH and Results

Questions	Agree	No Idea	Disagree
1. I have some difficulties while doing the traditional exercises.	**%100**	-	-
2. In the process of the treatmenet, I have mostly problem in my hands and arm.	**%75**	-	**%25**
3. I would like to need help while doing exercises.	**%60**	-	**%40**
4. When doing exercises, in a while time, I get bored and I give up doing exercises.	**%100**	-	-
5. I prefer games which include the traditional exercises, to doing exercises purely.	**%80**	**%10**	**%10**
6. My doctor gives some games to me for my treatment.	**%20**	-	**%80**
7. Exercises included computer games can be very motivated for treatment.	**%100**	-	-

5.2.1 Analysis of the Patients Test on VRH

From the first question, all patients have difficulties while they are doing daily life exercises. Therefore, all of the patients take traditional treatment for their therapy. In the second question, problematic areas are collected, %75 of patients have problems with their hand, hand wrist and arm motions. On the other hand, %25 of them suffer from other parts of their bodies. In the third question, which about getting help when doing exercises, %60 of the patients need help for doing traditional exercises. Actually in the doctors view, some of the patients are afraid of doing exercises by theirshelves. They always need help. However, at first they can be forced while doing their exercises,but then in a while of time they can adjust to make them. Furthermore, %40 of the patients wants to make these exercises by theirshelves which is most effective treatment for diffirent type of patients.

In the fourth question, patients answer the question which is about their exercises periodics, how many of them get periodical exercises. It is very common in the rehabilitation, most of the exercises are periodical, in other words iterative. There are very very few number of exercises are given which does not repeat in a while of time. As it can be seen from the results %90 of the patients get iterative exercises.

From this point, this is starting point of the study, iterative exercises and it is disadvantages. In question 5, it is very related with the question 4, all the patients are complained when they are doing traditional exercises, they get bored. Then for a while, they give up doing their exercises. In question 6, %80 of the patients, select playing game to doing iterative exercises. %10 of them are not sure about the playing games can be hlpful for their treatments. On the other hand, %10 disagree about the subject.

In seventh question, it is asked to the patients whether their doctor's give any game for their treatment. %20 of them play a game which is located in the rehabilitation center, after their exercises finish. Others do not play any game for their treatement. All the patients are agreed about the computer games increase the motivation of the patients and it is very important factor for the treatment process.

In the analysis of the questionnaire, most of the patients getting bored to doing traditional exercises. They prefer playing games to making these exercises. On the other hand, In our country, it is disappointing very few doctors give games for the part of a treatment. In the doctor's questionnaire this question also asked to the doctor's, the rate of answers are low as in the mentioned above. By getting results from doctor's and patient's questionnaire, study is developed for the hand, hand wrist and arm motion of the patients. As it can be developed most of the needed area of the patients in the future, in this thesis application is used for the improvement of neuro-rehabilitation patients.

To increase the motivation, to reduce the rehabilitation cost, to get objective solutions, to shorten treatement process in the neuro-rehabilitation phase, the study is accrued and will be generalized as soon as possible in all over our country.

5.3 Doctor's Interview

After the quantitive research, studies are concentrated in a specific area which is decided to neuro-rehabilitation patients. Interviews are made with these neuro-rehabilitation patient's doctors (See also Table-5). All the interview speeches are recorded, then speeches are transcribed, finally results are evaluated.

Table-5 Doctor's Interview

Doctor Questions
1. Did you use Virtual Rehabilitation games for your neuro-rehabilitation patients?
2. Which type of rehabilitation patients do you want to use VRH games?
3. How do you evaluate the game in the game system?
4. What is your opinion about the game system and it is advantages?
5. In this game system 8 game level are included. All the levels are developed for usage of the patients. Speed of balls, colors, dimensions are all different according to the level of the game. What is your opinion about this study?
6. In the game system, you can create your own game. What is your opinion about that?
7. What is your evaluations about system reports?
8. Is the system useful for the tele-rehabilitation?
9. Did you notice positive effects when applying game to the patients.
10. How studies which are carrying in this field, improved from past to now.
11. What is your suggestions to improve the system more?

5.3.1 Results of The Doctor's Interview

- From the start point which is question 1, there are a few games for applying the neuro-rehabilitation patients. So, medical executives have low chance to perform VRH games. It is collected that simple games are used for neuro-rehabilitation patients. However, these are not computer games or video games, these are some simple improvemental games. For example; for hand rehabilitation, colored ball game are used which patients try to grip soft balls. For arm rehabilitation, there is a apple tree game, patients try pick apples from the tree. This is used for arm neuro-rehabilitation. On the other hand, there is a game which is playing with an executive. That is, physical therapist holds his/her finger and patients try to hit the finger. Therapist holds his/her finger in randomly, then patients try to hit.
- In the second question, type of patients which the games are applied, are collected. After traditional treatment technics used for a while, that changes from patients to patients, it is related with the illness, that kind of games can be played by most type of rehabilitation patients. First type is, paralysed patients who have mental problems. Second type is, patients who suffers from injuries. Then an other of type patients who have broken part of the body. Arm brokens, finger brokens. And finally children patients for all types and children with obesity. In this thesis, neuro-rehabilitation patients are selected

to applying the game who have injuries in the hand, hand wrist and arm motions.

- When question 3 is asked to the doctors, which the evaluation of the game by the view of patients improvement, results are collected. Firstly, creating own game part is the most desirable part of the game, that gives chance to the medical executives and patients whatever the illness is, lots of games can be created and played. This is the first improvement in this field. Then, this system makes the use of iterative execises longer than before. Because it contains hidden exercises. In addition to this, motivation increase this is the most important improvement for the treatment of NR patients. In question 4, that is related with the question 3, utilities of the system is also asked to doctors. That is repeated most part the study, motivation is the head gain of the system. If motivation increase, treatment cost decrease and treatment time shortens. That is major start point in all types of health fields. In addition to this, game system hides the traditional exercises to the game. Patients making their exercises unawarely. Reporting phase of the system is helps the doctors to control their patients with scalar values.
- In question 5, game phases are detaily observed by the doctors. Evaluations of the 8 levels are collected. The structure of the game is suitble for the NR patients, that is from easy to difficult. Before selecting the game levels, sample definition are stored inside of all levels, that helps and reminds the content of all levels. Speeds, times, colors are all adjusted to level's aims. The detailed definition and pictures are shown in the Chapter-4. In all over levels are evaluated suitable for the NR patients treatment. From the interview of doctors, gripping motion is most intended study for the future work. That is evaluated for the future study.
- In question 6, creating any number of game phase is asked to the medical executives. They are all satisfied with this structure, this most important innovtaion in this study. In question 7, which is opinions about the reporting phase of the game system are collected. In this part, after the game finish, score, date and time informations are stored in the database. Informations are brought at the end of the game in same page with an understandable format. According to doctors opinions, reporting phase can be use for making

statistical analysis of NR patients and also their illnesses. In addition to this, patients can follow their stage of illness by using their scores. Question 8 is about tele-rehabilitation that is, patients continue their treatment at their homes. In this system, in the future client server relations will applied to the hospitals servers, for serving tele-rahabilitation term. By using this concept, doctors are agreed with the system concurrency to the tele-rehabilitation.

- In question 9 which is about the application of the game system to the patients then getting positive effects of the system. In the application of the system, after the starting of traditional exercises, game phase starts. Patients want to pass the game phase fastly, they are very excited for this phase. Then they start playing the game with a smiling face. This shows the positive effects of the system distinctly. It is inevitable that after motivation increase, treatment continue easily and time is shorten, that is explained before.
- In question 10, it is asked that the studies of this field from past to now, then ideas are received. In the past years, traditional exercises are applied to all types of rehabilitation patients. In some hospitals in the abroad, games are started to use which is mentioned in the chapter-2. These games are very similar with the games in gamelands. However, it is difficult to use these games for heavy stroke patients and also for big rehabilitation centers it is costly to buy enough number of games for their patients. In addition to this, it is an effective introduction for the studies in this field. Then computer video games is used in this area. Next, wii-based games are used in the world, but this technology newly use in our country. After that simulations are made which are highly complex system, at the same time they are very similar with the real time objects and real time actions. Finally, from 2002 to now, web-cam approach started to use, in this approach, cables and extra units are removed. Direct access is developed between computer and human.

Finally, future works for the system is collected at the end of the interview. Client server, relationship between patients and the hospital or a rehabilitation center is first future study intended from executives. In addition to this, gripping objects is an other desired study for the future, but again without using any extra apparatus and cables. Similar games with shoulder rehabilitation is also wanted which controls the patients,

whether the arm is fully hold or not. If patients can not hold their arm fully, an alert is sended to the patients. Moreover, 3D version of the game system is an other viewpoint collecting from medical authorities. To make 3D game, two or more cameras are needed, after applying game 3D version, lots of game can be developed for other area of the rehabilitation patients. For example; for leg, knee and ankle rehabilitation.

This study, starts new era for lots of innovations which can improved in the future. Therefore, studies will continue in this field, after the thesis completion.

5.4 Visual Analysis of the Questionnaires

Unlike chapter 3, in this field questionnaire results are examined by using graphical way.

5.4.1 Doctor's Questionnaire

In doctor's questionnaire, questions are grouped into the five categories according to their types.

Rehabilitation and Traditional exercises

In this group, there are three questions which are the first three questions. They are all about the rehabilitation and traditional exercises. In the first question, the body part of rehabilitation patients are asked which needs rehabilitation treatment at most and the results are shown in the Figure-38 which is below.

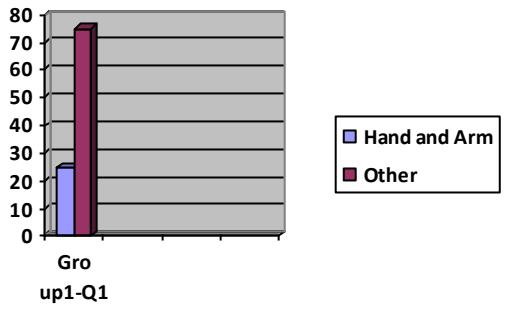

Figure-38 Patients treatment area

The results of the second question, in group-1 show that, active and passive exercises use for the treatment of the rehabilitation patients. However, there are also some other methods which are used for the patients according to their illness (see also Figure-39).

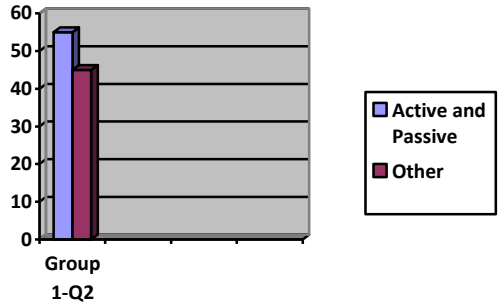

Figure-39 Active and passive exercise usage

Final question of group-1 is about the efficiency of active exercises, rather than passive exercises that means, patients do their exercises by their shelves (see also Figure-40).

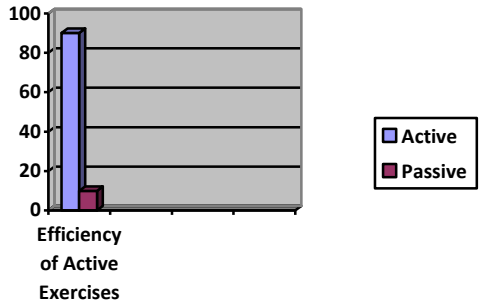

Figure-40 Efficiency of the active exercises

Traditional Exercises and Their Effects to the Motivation

Group 2 contains only one question which is about the traditional exercises and their effects to the motivation. The results of the question 4, point that patients who needs physical therapy and rehabilitation, get bored in a while of time when they are doing their exercises. There is a different to understand the motivation factor in traditional exercises (see Figure-41).

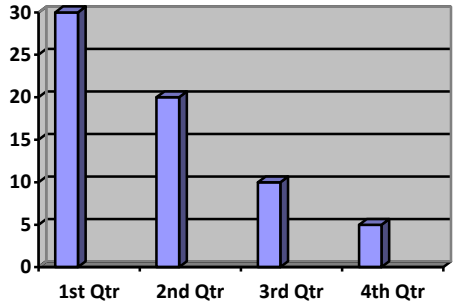

Figure-41 Motivation factor after applying the traditional exercises in a while of time.

Rehabilitation Games

Question 5, 6, 7 and 8 are composed the third group of the questionnaire. They are about the games specially rehabilitation games for the treatment. Questions are asked that whether the games can be used for the rehabilitation treatment. Whether the active exercises is hidden to the games and can the VRH games can be used for the rehabilitation patients. Results are shown in the Figure - 42, mostly executives are agreed with the topic.

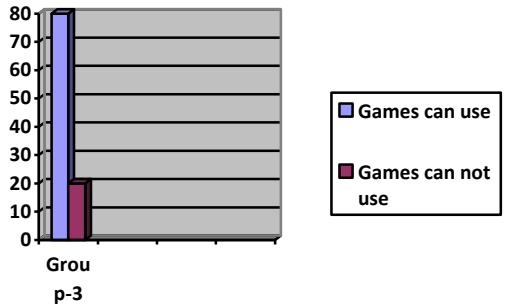

Figure-42 Games usage for the treatment

VRH Games

VRH games and their usage are asked in group 4. Firstly, how many executives know about VRH and it is games are collected from rehabilitation centers. That is shown in the Figure-43 and also results are disappointing for the study. After displaying some examples of the VRH games, benefits of the games are again collected (See Figure-44).

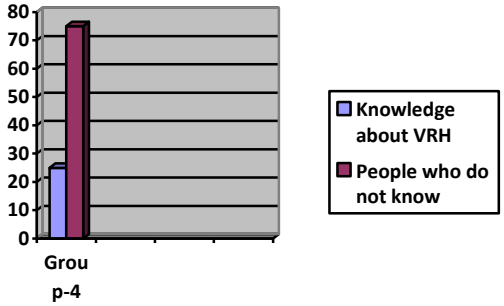

Figure-43 Knowledge about the VRH and it is games

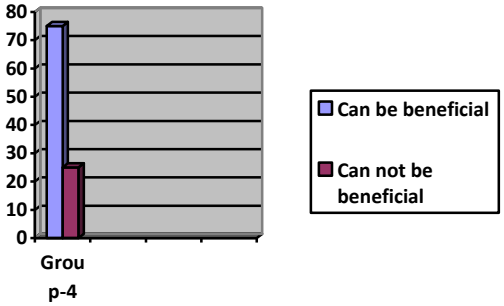

Figure-44 Opinions about the games benefits

In Turkey, there is very few number of center use VRH games and it is costly that purchasing these VRH games, that is gained after asking to the medical executives. Numerical results are shown in Figure-45.

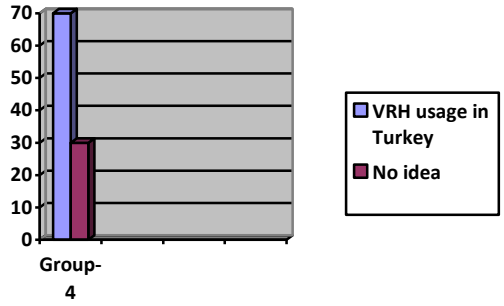

Figure-45 In Turkey few medical centers uses the VRH and it is games.

System Usage

Final group collects the results of the usage of our system can be beneficial and decrease the cost of treatment for most type of rehabilitation patients. All the medical authorities agree about the topic.

5.4.2 Patient's Questionnaire

In patients questionnaire there are 3 groups in respect of their contents.

Difficulties of Patients in Daily Life Activities

In the first group, there are 2 questions. That is about the daily life activities and it is difficulties for the patients. Half of the patients have difficulty while they are doing their daily life activities. Additionally most of suffer from their hand and arm motions. Results are also shown in the Figure-46 and Figure-47.

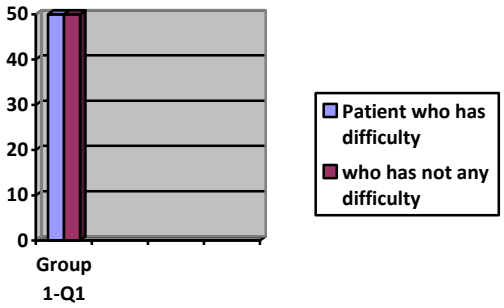

Figure-46 Patients difficulty I the daily life activities

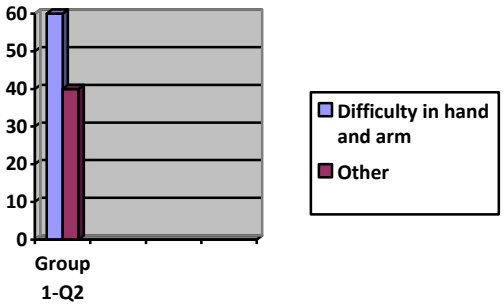

Figure-47 Area of patients who suffer from

Repetitions in Traditional Exercises

Question 3, 4, 5 and 6 are included in group 2. Content of that group is, iterative traditional exercises and their effects to the patient's motivation. Most of the patients need help while they are doing their exercises (See Figure-48). Most of the patients, apply their exercises in a period of time. That makes all of the patients get bored while they are doing their exercises after in a while of time. Figure-49 shows the graphical view of number of patients who are doing iterative exercises.

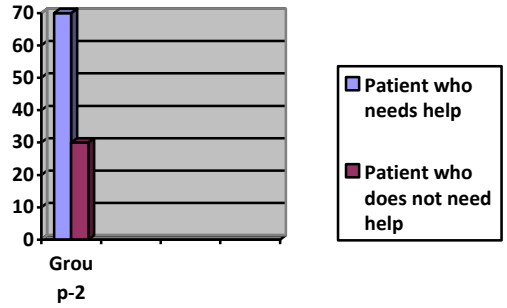

Figure-48 Number of patients who need help while they are doing their exercises

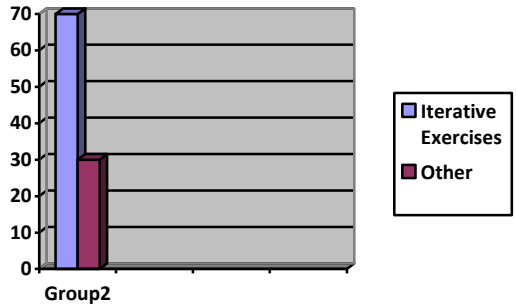

Figure-49 Number of the iterative exercises

Patient's Choice of the Game

The substance of the group 3 is about patient's choice of games for treatment rather than traditional exercises. Patients all agreed that playing games more preferred treatment type than traditional exercises. They also participated that games increase the motivation, so treatment with games also better choice for the patients. Additionally, few of the patients play games which are given from their doctors, for their treatment. That is shown in the Figure-49.

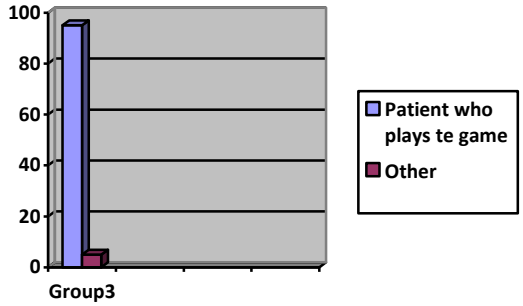

Figure-50 Patients who play games for their treatment

5.5 Application to the Patients

Final process of the study is the application of the game to the rehabilitation patients. To make this application two child rehabilitation patients are selected and the game is applied after patients finish their traditional exercises. In the following part, application of the treatment and the results are explained.

5.5.1 First Child Patient

The first patient is 9 years old boy. He has a problem with his arm, his arm nerves are bruised when he had born. He had been taken traditional exercises for a long time. The game is applied to the patient in three weeks. By the help of the rehabilitation center, the game was reflected to the projection to playing easily (See also Figure-51).

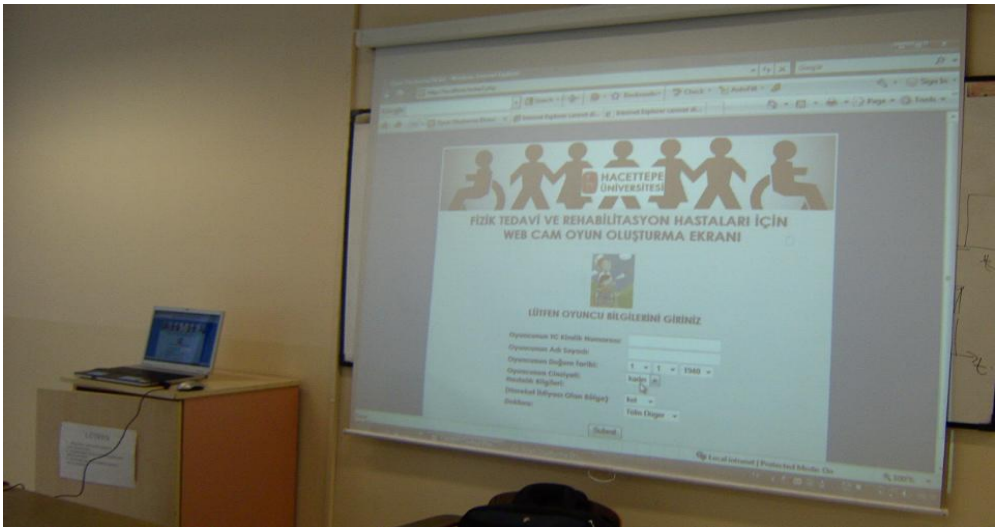

Figure-51 Reflection of the game

1- Doctors Observations

First of all, when the game was applied to the patient, his doctor and physical therapist were followed the patient. The first sentence when the child started to the game is, they were trying to hold his arm up as much as possible in a long time, but they had difficulties to make this action. However, child was hold his arm to the up side more than traditional exercises at the very beginning of the game (See Figure-52, 53).

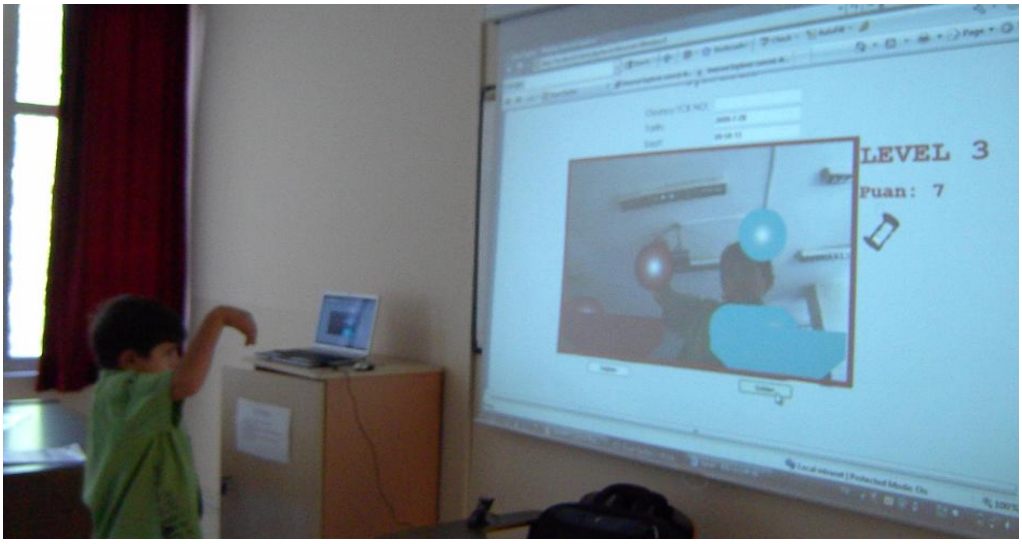

Figure-52 First child patient level 3

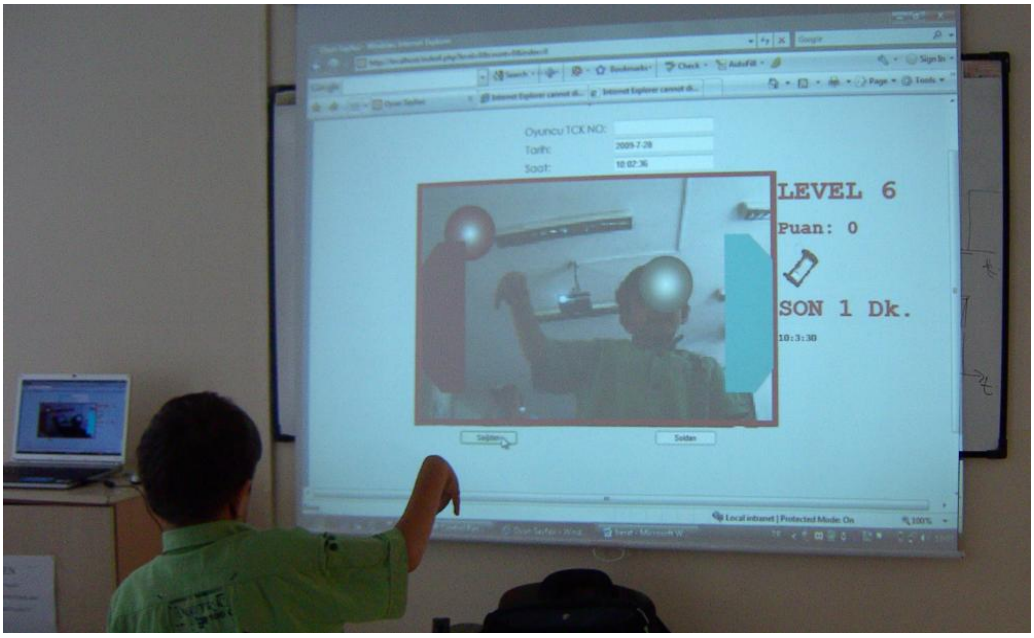

Figure-53 First child patient level 6

Moreover, he tired when he plays 2 level of game. So that shows, the first child patient should play the game which includes two levels. Doctors should create his games by selecting two levels.

2- System Observations

The application of the game to the rehabilitation patients, are amazing for the study and patient also happy with that part of his treatment. He adapted easily with the game and he likes the game. From that view, it is seen that the game shortens some process of the traditional exercises. Additionally, patient enjoying while he playing the game. At the beginning doctors give 30 minutes for the game to treatment. However, child prolongs the time voluntarily. Furthermore, the patient is blended to the game easily. He increases his score fastly in the levels of the game (See also Figure-54).

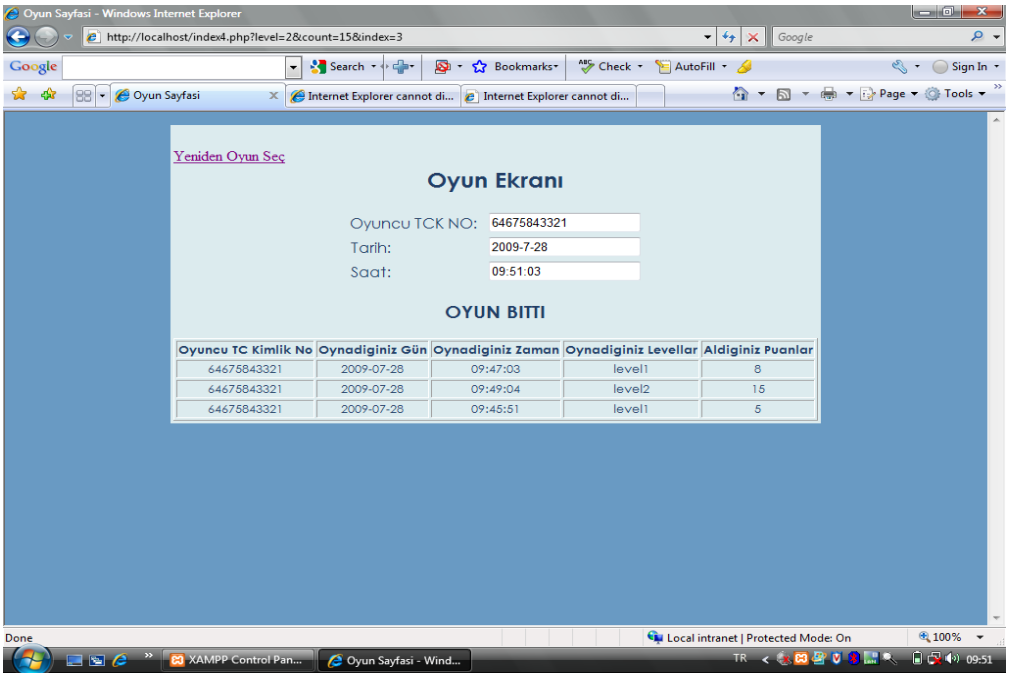

Figure-54 First patients result

3- Patient's Comment

The boy said that he likes the game and he also prefers the same kind of games which includes boxing or fighting. He plays computer games by using joystick or keyboard.

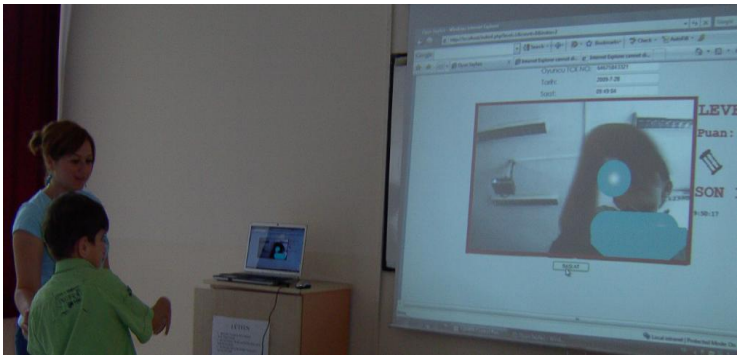

Figure-55 First patient application

5.5.2 Second Child Patient

The second child patient is 13 years old boy. He has mental problems which means, he is suffering from cognitive difficulties. For this reason, he needs the therapy. The upper levels of the game is applied to that patient. Because these levels measure the selectivity, so it is suitable for that kind of patients (See also Figure-56).

Figure-56 Second child patient

1- Doctors Observations

For the second patient, it can be easily said that, he adapts the game much faster than the first patient. Because he has a very little physical problem, he has cognitive problem. He increases speed of his arm while he was playing the game. Doctors were very happy with the helpful system after the application was finished. They also think the motivation factor it is also increases when patient playing the game. Additionally, physical therapist of the patient said that in most of the traditional exercises, the patient make some disunities. However, the patient is very quiet while he playing the game. He only focuses the game. That shows an elusive feature of the game, that is concentration. That application shows that game increase the concentration of the patients who has mental problems.

2- System Observations

The scores of the second patient are very great for his doctors. That is because of his fast adaption to the game. It can be easily observed the second patient is more durable than the first patient (See also Figure-57, 58).

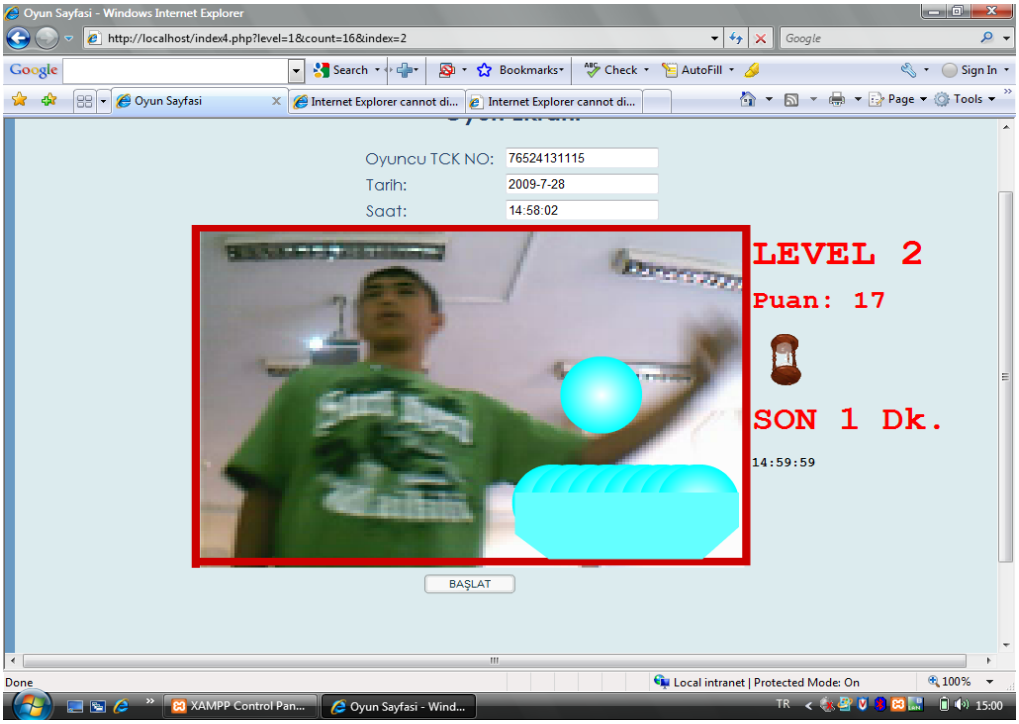

Figure-57 Second patient application

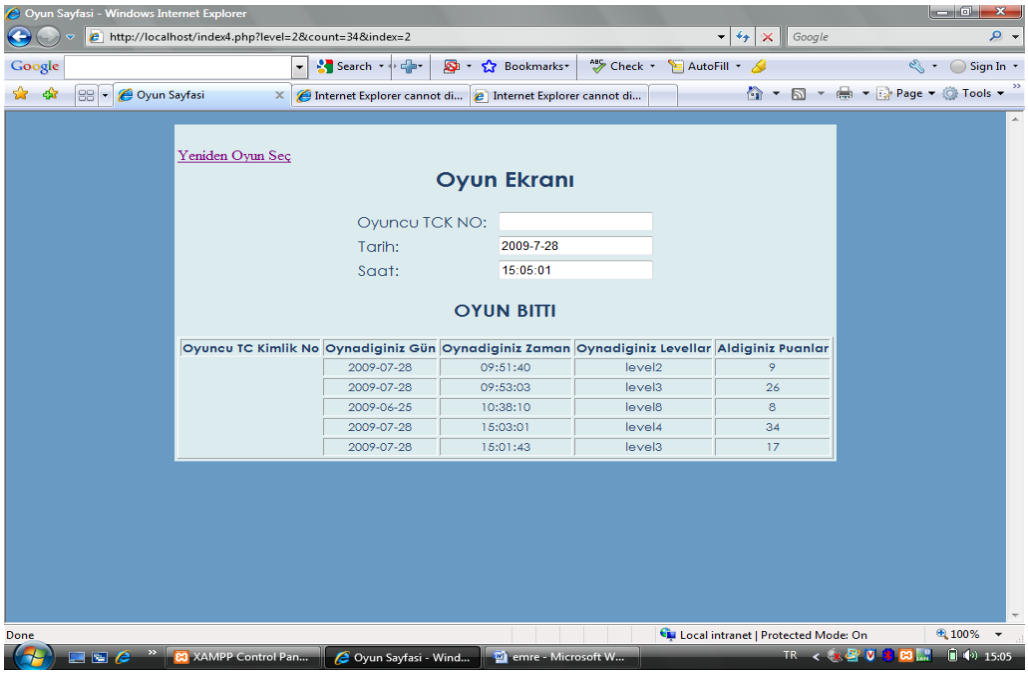

Figure-58 Scores of the second patient

3- Patient's Comment

He said that, he likes the game very much. He also added that, not only balls are falling down from the screen but also random shapes can be falling to the screen. Boxing or fighting also intended game types for the patients that is related with the genders of the two patients.

5.6 Final View

The applications of the patients are continue. For the first patient, the game will be applied in 6 months and for the second patient it is applied n 5 months. The center wants to study about this subject with us, then we will be work together for the future works. There are some additions for the future that are mentioned in Chapter 6.

CHAPTER 6

CONCLUSION

The study presents the necessity for developing and applying game based Virtual Rehabilitation Systems in Turkey. Because the studies received great deal of contributions from the medical authorities, studies must raise in that areas and much more improvements should be presented to the patients. Investigations show that patients prefer simple understandable systems rather than complicated applications. The game has very low system requirements. That means that, the majority of the patients will not need to wear or purchase any additional apparatus, units and equipments. Therefore, the system can apply more effectively than the other systems.

By comparison with the studies in this field shows that in Turkey there are very few studies can be shown. Mostly, they are used for the some typical and simple treatment. In TSK rehabilitation center is used these type of treatments. However, in abroad there are effective studies for the rehabilitation patient's treatment. Moreover, there are not any studies like the developed game system. There are games which give one alternative for the treatment. This study not only presents lot of alternatives for most of the rehabilitation patients but also reports the results of the patients.

A paper prepared about the study and send to the HIBIT international health information symposium, and then it is accepted from METU Medical Informatics department. The presentation is hold in the symposium in the METU [15].

6.1 Contributions with the Analysis of Results

Results collected from both doctors and patients show that the game system contributes the physical therapy and rehabilitation field of health. In the overview of the system, traditional exercises were hidden to the eight level of the game system for the NR patients who need these types of exercises for their hands, hand wrists and arms. Additionally, system also serves for medical executives. By entering patient's conditions, doctors or physical therapists can created large quantities of different games by selected levels of the games. That is the important innovation part of the study and it is admired by all the medical authorities. Then, after the patients play their games, system displays a report for the patients and their doctors in an understandable way. Reports contain patient's level, score, time and date information. By using these reports, doctors follow their patient's treatment process effectively and objectively. The game system can also be used for the patients with arm or hand breakage, children patients, for patients with newly usage of their prosthesis and patients who have problems with their arm and hand motions. After the meetings of the medical centers, there are lots of improvements are collected for the future work.

6.2 Future Works

Our research results have shown that gripping is an important exercise for the patients in this field. In the future all the small part of the hand or arm can be perceived from the system by only specifying the color. That means, in the future this type games are capable of including more and different type of exercises by capturing the motion from different colors. So in the future, web-cam approach applications can be improved like simulation based VR applications without wearing or using any extra units.

In addition to this, by using more than one web-cam, these types of games can be applied to the 3D environment. And also, games can be developed for the rehabilitation patients for all body motions. For example; leg, head, knee motions. Large number of games can be develop for the future usage. Most of the medical centers make the study as a project for the future works.

REFERENCES

[1] Prange, G.; Krabben, T.; Molier, B.; van der Kooij, H.; Jannink, M., ***"A low tech virtual reality application for training of upper extremity motor function in neurorehabilitation"***, Virtual Rehabilitation Workshop, Vancouver Convention & Exhibition Center, Canada, August 25-27, 2008, Page(s): 8-12.

[2] Burdea G., ***"Keynote Address: Virtual Rehabilitation-Benefits and Challenges",*** 1st International Workshop on Virtual Reality Rehabilitation (Mental Health, Neurological, Physical, Vocational) VRMHR Lausanne, Switzerland, November 7 and 8 2002 :pp. 1-11.

[3] Wilson, Peter H.; Duckworth, Jonathan; Mumford, Nick; Eldridge, Ross; Guglielmetti, Mark; Thomas, Patrick; Shum, David; Rudolph, Heiko, ***"A virtual tabletop workspace for the assessment of upper limb function in Traumatic Brain Injury (TBI)",*** Virtual Rehabilitation Workshop, Venice , Italy, September 27-29, 2007, Page(s): 14-19.

[4] Ramchandani, A.; Carroll, K.; Buenaventura, R.; Douglas, J.; Justin Liu, ***"Wii-habilitation increases participation in therapy",*** Virtual Rehabilitation Workshop, Vancouver Convention & Exhibition Center, Canada, August 25-27, 2008, Page(s): 69-69.

[5] Reinkensmeyer, David J.; Housman, Sarah J., ***"If I can't do it once, why do it a hundred times?": Connecting volition to movement success in a virtual environment motivates people to exercise the arm after stroke",*** Virtual Rehabilitation Workshop, Venice , Italy, September 27-29, 2007, Page(s): 44-48.

[6] Huber, M.; Rabin, B.; Docan, C.; Burdea, G.; Nwosu, M.E.; Abdelbaky, M.; Golomb, M.R., ***"PlayStation 3-based tele-rehabilitation for children with hemiplegia",*** Virtual Rehabilitation Workshop, Vancouver Convention & Exhibition Center, Canada, August 25-27, 2008, Page(s): 105-112.

[7] Carvelho, T.; Allison, R.S.; Irving, E.L.; Herriot, C.,"***Computer gaming for vision therapy",*** Virtual Rehabilitation Workshop, Vancouver Convention & Exhibition Center, Canada, August 25-27, 2008, Page(s): 198-204.

[8] Guberek, R.; Schneiberg, S.; Sveistrup, H.; McKinley, P.; Levin, M.F.," ***Application of virtual reality in upper limb rehabilitation",*** Virtual Rehabilitation Workshop, Vancouver Convention & Exhibition Center, Canada, August 25-27, 2008, Page(s): 65-65.

[9] Toru Fujimoto, Fumitaka Beppu, ***"Games for Health in Japan",*** Games for Health Conference 2006, 29 August 2006.

[10] Jodie Sinnema, edmontonjournal.com***, "Wii technology used in brain rehabilitation (3 p.m.)",*** Published: Friday, May 11 2007.

[11] *Wii-hab,* ***"Video Games Are Becoming the New Trend in Rehabilitation Hospitals",*** *Megan Drummond, Mar 19, 2008.*

[12] Patrice L. Weiss, Rachel Kizony, Uri Feintuch and Noomi Katz, ***"Virtual reality in neurorehabilitation".***

[13] R. F. Boian, G.C. Burdea, J.E Deutsch, and S.H. Winter, ***"Street Crossing Using a Virtual Environment Mobility Simulator"***, To appear in the Proceedings of IWVR 2004, Lausanne, Switzerland.

[14] Sandeep Subramanian, Luiz A Knaut, Christian Beaudoin, Bradford J McFadyen, Anatol G Feldman and Mindy F Levin, ***"Virtual reality environments for post-stroke arm rehabilitation"***, Journal of NeuroEngineering and Rehabilitation, Published: 22 June 2007.

[15] Leyla Sezer, Nergiz Ercil Çağıltay, ***"improving the functions of the arm and hand motions of rehabilitation patients by using a mixed reality game"*** , HIBIT International Conference in METU, April 2009.

APPENDIX A

Rehabilitation Executives Attitude Test on VRH

Fizik Tedavi ve rehabilitasyon, herhangi bir nedenle kaybedilmiş fonksiyonların günlük yaşamda yeniden bağımsız duruma gelmesini sağlamak amacı ile verilen hareketlerdir. Omuz, kol, bacak eklemlerinde ağrıları olanlar, beyin, sinir hasarı sonucunda kol ve bacaklarında felç geçirenler, kırık çıkık, incinme nedeniyle alçı sonrasında eklemlerinde sertleşmeler olanlar, fizik tedavi ve rehabilitasyon uygulanacak hasta grubuna girerler. Bu tedavi sürecinde, hasta için özel olarak geliştirilmiş olan oyunlardan yararlanabilme konusunda görüşlerinizi almak için hazırladığımız aşağıdaki anketi doldurarak çalışmamıza katkıda bulunursanız çok teşekkür ederiz.

Sorular	Katılıyorum	Fikrim Yok	Katılmıyorum
Bu tür tedaviye en çok ihtiyaç görülen alanlar arasında kol ve bilek kısımları yer almaktadır.			
Fizik tedavi ve rehabilitasyon sürecinde verilen hareketler pasif ve aktif hareketlerdir.			
Aktif hareketler (hastanın kendi kendine kimsenin yardımını almadan yaptığı hareketler) hastanın iyileşme süreci için en verimli olan hareketlerdir.			
Hastaların tedavi sürecinde pasif ve aktif hareketler uygulanırken bazı tekrarlı hareketlerde sıkıldıkları görülmektedir. Bu motivasyon kaybına sebeb olmaktadır.			
Hastaların tedavi sürecinde, özel tasarlanmış oyunlardan yararlanılabilir			
Hasta tedavisinde kullanılan aktif hareketler için bilgisayar oyunlarından yararlanılabilir			
Hasta tedavisinde kullanılan pasif hareketler için bilgisayar oyunlarından yararlanılabilir.			
Her yaştaki hasta grubu için rahatlıkla uygulanabilecek oyunlar sanal rehabilitasyonda vardır.			
Sanal rehabilitasyonda kullanılan oyunları incedim, biliyorum			
Sanal rehabilitasyonda kullanılan oyunların faydalı olabileceğini düşünüyorum.			
Yurt dışında sanal rehabilitasyon alanında çeşitli ürünler üretilmiştir, ancak bunları ülkemiz için satın almak oldukça maliyetlidir.			
Ülkemizde üretilmiş ve rehabilitasyon merkezlerinde kullanılan sanal rehabilitasyon oyunları yoktur.			
Hastaların tedavisi için özel tasarlanmış ve maliyeti düşük bir oyun sistemini kullanmak isterdim.			
Tedavi sürecinde kullanılan oyunların motivasyon açısından hasta üzerinde olumlu etkileri vardır.			
Tedavi sürecinde kullanılan oyunlar tedavi süresini kısaltabilir			
Tedavi sürecinde kullanılan oyunlar tedavi maliyetlerini azaltabilir.			

APPENDIX B

Rehabilitation Test on Patients

Sorular	Katılıyorum	Fikrim Yok	Katılmıyorum
Doktorumun verdiği fizik tedavi hareketlerini yaparken zorluk çekiyorum.			
Tedavim sırasında en çok elimi yada kolumu kullanırken zorluk çekiyorum.			
Egzersizlerimi yaparken zorluk çekiyorum ve birinin yardmına ihtiyaç duyuyorum.			
Doktorum düzenli olarak yapılacak hareketler verdi.			
Doktorumun verdiği hareketleri yaparken belli bir süre sonra sıkılıyorum ve hareketleri yapmak istemiyorum.			
Doktorum bana tedavimin bir parçası olarak bazı oyunlar verdi.			
Egzersizlerin içinde bulunduğu bir bilgisayar oyunu oynamak isterdim.			

APPENDIX C

Doctors Interview

Sorular
1. Neuro-rehabilitasyon hastalarınız için Sanal Rehabilitasyon oyunları kullanıyor musunuz?
2. Sanal rehabilitasyon oyunlarını ne tip hastlarınız üzerinde uygulamak istersiniz?
3. Oyun sistemindeki oyunları nasıl değerlendirirsiniz?
4. Oyun sistemimiz hakkındaki görüşleriniz nelerdir ve sizce avantajlarını nelerdir?
5. Oyun sistemimizde 8 ayrı seviye bulunmaktadır? Her bir seviyede farklı farklı özellikler hastalar için uygulanmıştır. Bu konudaki görüşleriniz nelerdir?
6. Oyun sistemimizde her hastaya uygun olarak farklı farklı oyunlar oluşturulabilmektedir. Bu konu hakkındaki görüşleriniz nelerdir?
7. Sistemimiz oyun sonunda raporlama yapmaktadır. Bu konu ile ilgili neler söylemek istersiniz?
8. Sistemimiz ilerisi için tele-rehabilitsyon uygulaması için uygun mudur?
9. Hastalara uygulama aşamasında sistemimizde ne gibi olumlu yönler fark ettiniz?
10. Bu alanda dünden bugüne ne gibi çalışmalar yapılmıştır?
11. Sistemiz ile ilgili ilerisi için önerileriniz nelerdir?