# Understanding the Adoption of Interactive Technologies in Rehabilitation

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**Abstract**

Physiotherapy is a clinical practice that aims to improve the lives of patients suffering from an injury, trauma or genetic alteration. The physical therapy gyms are often very crowded, not allowing the physiotherapists to dedicate as much time as the patients need. In addition, physiotherapists need simple and accurate tools to assess patients' performance. Although there are some application proposals in the state of the art, they are still not adopted in real clinical contexts. In this work, we distributed a questionnaire, based on the Unified Theory of Acceptance and Use of Technology, by 116 physiotherapy professionals and students who defined the intention to use markeless motion capture systems as a function of facilitating conditions, performance expectancy and habits. Additionally, we proposed an interactive upper limb rehabilitation system, ARCADE, which uses Kinect, a markerless motion capture camera. A demonstration and evaluation of the prototype was conducted with physiotherapy students. At the same time, the system was placed in the gym of a physical rehabilitation clinic for ten days to evaluate its use by physiotherapists. The results show that our system is simple to use, corresponds to the professionals' requirements, presents reliable measures and motivates physiotherapits and patients.
**Keywords:** Physiotherapy, Adoption, Unified Theory of Acceptance and Use of Technology, Markerless Motion Capture, Kinect

## 1. Introduction

Although there are multiple and well defined exercises for each patients' profile, there is still a lack of exploration of the contribution that technology, and markerless capture systems in particular, can bring to these therapies.

Physiotherapists (PTs) reveal that, in a clinical environment, they have a short amount of time to take care of their patients and it has to be harnessed to the maximum, making it more difficult to adopt systems involving the placement of markers in the patients' body, since such a task and subsequent calibration may consume time indispensable for treatments. This problem can be solved by markerless motion capture systems, which tend to be less accurate but much more practical for these environments. Although some tools are already developed with these technologies, their acceptance and adoption are below expectations and few are used in daily life. In addition, many have only been evaluated in controlled laboratory settings, thus not corresponding to the needs and difficulties encountered in the clinical environments. It is therefore necessary to study which facilitators and barriers affect the intention to use these systems by physical therapists in physical rehabilitation clinics.

This paper also proposes an interactive system, ARCADE, for upper body limb rehabilitation, with a markerless motion capture camera, Kinect for Xbox360. This system makes it possible to speed up treatments and the clinical process of performing exercises and recording results.

This paper presents several contributions to the medical and scientific community, including: results of a questionnaire based on the Unified Theory of Acceptance and Use of Technology, explaining the constructs that influence the intention to use markerless motion capture systems; development, through user-centered design methodologies, of an interactive application with upper limb rehabilitation exercises; quantitative and qualitative evaluation of the proposed system, with physiotherapy students (PSs), using a questionnaire and an interview about their intention to use it; qualitative evaluation with three physiotherapists, for two weeks in a clinical environment, of the proposed system, identifying the facilitators and barriers encountered.

## 2. Theories of Adoption and Acceptance Models

Technology is present in practically every moment of our day-to-day life. Nevertheless, there are products that are not as successful as desired among their target audience. To try to understand technology adoption and acceptance, some models and theories are briefly presented, in descending order of use by the scientific community.

### 2.1. Technology Acceptance Model (TAM)

Created in 1989, TAM is the most widely used model for IT adoption studies and describes the factors that influence users to embrace new technology. TAM focuses on two key concepts: perceived usefulness and perceived ease-of-use. Perceived ease-of-use reveals how simple the user thinks it is to use the system and perceived usefulness reveals how useful the user thinks the system is for him and the task he wants to perform [7]. TAM does not provide any information on how technology should be built and developed, only reinforces that it should be intuitive and useful.

### 2.2. Diffusion of Innovations (DOI)

DOI was proposed by Rogers in 1962 and has since been revised and extended multiple times. This theory states that the principles for technology acceptance are based on innovation, communication channels, time and social system and are intended to explain how it spreads through users [21].

The five key factors, according to DOI, for IT adoption are: the usability advantage (how better it is over existing solutions); compatibility (perception that the solution adapts to existing processes); the complexity; experience (innovation can be tested and modified); and observability (the results of innovation are clear).

### 2.3. Unified Theory of Acceptance and Use of Technology (UTAUT)

UTAUT was built on eight other acceptance theories to bring all key concepts together into one. Thus, it combines concepts from TAM, TRA, Motivation Model, TPB, Combined TAM and TPB, The Model of PC Utilization, DOI and Social Cognitive Theory. This model aims to predict user's behavior when using technology based on their intentions.

In 2012 it was adapted and extended by Venkatesh for UTAUT2 with seven base pillars: performance expectancy (user's belief in the support that technology will do to the work they have to do); effort expectancy (perceived ease of use by the individual); social influence (user's perception of what others think about the system); facilitating conditions (user's perception of the external support they have for using the system); hedonic motivations (fun or joy in using the system); price value; and habit [26]. The theory further argues that variables such as age, gender and experience may interfere with some of the previously described constructs.

### 2.4. Theory of Planned Behaviour (TPB)

TPB intends to understand the reasons for people's actions. The theory is based on a few fundamentals: the user's attitude towards the act or behavior (the user's perception of the benefit of the act or behavior for his life), the subjective norm (influence of the people or systems surrounding the user) and the perception of behavior control (user belief about the ease of performing the action) [13, 19]. These are the bases that formulate the intention of the user and then determine his action.

## 3. Related Work

This section will explore the work already done in the literature and expose several technology adoption studies in the medical field, interactive upper limb rehabilitation systems, and validation studies on the use of Kinect as a markerless motion capture technology for physical rehabilitation.

### 3.1. Technology Adoption in the Medical Field

The most used model in the state of the art is UTAUT [26], since it is one of the most recent theories and brings together the constructs of many others. The most common method for these studies is the use of questionnaires to further evaluate the technologies according to the model constructs.

Alaiad and Zhou sought to understand the determinants for the adoption of Home Healthcare Robots [1]. These robots are tools built to reduce the number of doctor visits, to improve the quality of post-hospital care, to increase patients' independence and to increase patients' safety through constant real-time diagnostics. The authors chose to adapt the UTAUT and add some constructs. They concluded that the intention to use their robots depends on performance expectancy, social influence, trust, concerns about privacy and ethics, and facilitating conditions.

A study by Liu et al. [16] aimed to discover the barriers and facilitators of the use of new technologies for physical rehabilitation. Using UTAUT, they discovered that performance expectancy is the factor that mostly influences the intended use of these systems. Effort expectancy and social influence, on the other hand, obtained insignificant results, thus emphasizing that the degree of difficulty or social pressure does not influence the decision of therapists.

To try to identify the barriers faced by hemiplegic patients in the use of technologies and the use of social networks in a rehabilitation context, Tatla

et al. [24] conducted semi-structured interviews with PTs. They highlighted, from their results, the following barriers: patients' frustration when unsuccessfully using videogames; multiple tastes for games and social networking by customers; age limitations for games and social networks; privacy issues when using social networks; difficulty in representing everyday exercises in videogames; lack of accessibility to games that adapt to the patients' needs; and also the reformulation of the role of the physical therapist in a game session. Still, they pointed to the potential for interpersonal relationships between patients and their increased motivation.

As far as we know, these were the only studies in the literature conducted with PTs about the adoption and acceptance of technology.

### 3.2. Interactive Systems for Upper Limb Physical Rehabilitation

The technologies used in the literature are diverse and work mainly in two different ways: with or without the use of markers on the patient's body. For markerless technologies, Kinect, a markerless motion capture sensor originally developed for the Microsoft Xbox 360, is the most used hardware. As for marker-based technologies, the choice is wide and depends mainly on the system to be developed and the metrics to be obtained.

Although the advantages of using these systems are noticeable, there are several issues to be aware of when designing them. The first is how patients are motivated to use them. One of the following techniques to solve this problem is gamification. The most recurring gamification techniques are the use of punctuation and classification [17, 18, 22], timers [3, 17, 25] and obstacles [3]. The second problem is related to the techniques that allow simulation of the PTs' support to guide the patients in the practice of the exercises. This can be solved with correct biofeedback. There is several information that is often showed, such as: the trajectory of the movement [9, 17, 22], the angles of the joints [9, 17], the range and speed of movement [17], the duration of the exercises [22, 25] and the compensatory movements [9, 25]. Tang et al. [23] also developed Wedge, a guide in real time to execute upper limb exercises.

It is important for patients and especially for PTs to be involved in the process of designing the systems so that the solution meets their expectations and needs. The most recurrent techniques are the use of questionnaires [18, 22, 23], observations [9, 22, 23, 25] and interviews [9, 23, 25]. Only one of the systems found in the literature, TagTrainer [25], has been evaluated in a clinical environment. Despite this, the study focused on the difficulties in creating and interpreting feedback for patients and not on the needs and expectations of usability of PTs regarding it.

### 3.3. Kinect Validation for Physical Rehabilitation Applications

Kinect is a camera designed for the Xbox 360 and allows capturing motion without having to place markers on the body. This technology is capable of identifying 20 joints of the human body and multiple bodies simultaneously. Its accuracy is repeatedly questioned as the camera does not use markers.

Fern'ndez-Baena et al. [10] believe that physical rehabilitation systems do not require a very high level of accuracy and, to prove it, developed the Rehabtimals application that allowed patients to play serious games at home. They then compared the results obtained by the Kinect camera with Vicon (set of 4 to 32 cameras, with markers). The angles between body segments were verified and the Kinect error never exceeded 10º. Kinect was again compared to Vicon systems by Bonnechere et al. [4] and Ross et al. [5] and the conclusions are the same: the results are very similar and the errors are often insignificant. The only disadvantage of Kinect is the non detection of segment rotations.

## 4. Markerless Motion Capture Systems Adoption: UTAUT survey

To understand the intention of using markerless motion capture systems, we used UTAUT, previously explained.

### 4.1. Research Model

Based on the constructs defined by UTAUT, the following hypotheses were formulated:

**H1** Performance Expectancy has a positive effect on the intention to use the systems.

**H2a** Effort Expectancy has a negative effect on the intention to use the systems.

**H3a** Social Influence has a positive effect on the intention to use the systems.

**H4** Facilitating Conditions have a positive effect on the intention to use the systems.

**H5** Hedonic Motivation has a positive effect on the intention to use the systems.

**H6** Price Value has a negative effect on the intention to use the systems.

**H7** Habit has a positive effect on the intention to use the systems.

TAM also proposes a relationship between perceived ease-of-use and perceived usefulness [7]. Thus, and as proposed by Alaiad and Zhou [1], we add a hypothesis that aims to verify whether there is an indirect influence of effort expectancy on intention to use through performance expectancy.

**H2b** Effort Expectancy has a negative effect on Performance Expectancy.

Alaiad and Zhou [1] also propose four new constructs: trust, privacy concerns, ethical concerns and legal concerns. This constructs were build based on other adoption studies in literature. Thus, the following hypotheses are added:

**H3b** Social Influence has a positive effect on Trust.

**H8** Trust has a positive effect on the intention to use the systems.

**H9a** Privacy concerns have a negative effect on the intention to use the systems.

**H9b** Privacy concerns have a negative effect on Trust.

**H10** Ethical concerns have a negative effect on the intention to use the systems.

**H11** Legal concerns have a negative effect on the intention to use the systems.

#### 4.2. Method

The survey questionnaire was administered online and distributed by PTs and PSs. Participation was valid regardless of gender, age or past experience with the technology. A link for the survey was distributed in Escola Superior de Saúde Egas Moniz, by email through Associação Portuguesa de Fisioterapeutas and during the 4th International Congress of CiiEM 2019. The participation was voluntary. One randomly chosen participant was awarded a 20 EUR FNAC card. Validation that the sample size is sufficient for testing the research model can be done using two statistical power methods: the 10 times rule of thumb strategy [8] and Cohen's recommendation [6] using the G*Power software. The minimum number of responses for this study is 110 (maximum number between the 10 times rule of thumb strategy and Cohen's recommendation).

#### 4.3. Procedure

The questionnaire was hosted online on the Google Forms platform. It was broadcasted by participants via direct link, mailing list or private message and by QR Code.

The questionnaire included a section explaining markerless motion capture systems with text, image and video, in order to ensure that participants clearly understood the study object. Participants were also informed that the questionnaire filling would have an average duration of 10 minutes.

#### 4.4. Survey items

Items related with the original UTAUT constructs were taken from the original model [26]. The items related with trust, privacy concerns, ethics concerns and legal concerns were taken from the study by Alaiad and Zhou [1]. All of these items have been modified for the context of markeless motion capture systems and translated into Portuguese. Responses to the statements were given on a discrete Likert scale between 1 (Strongly Disagree) and 7 (Strongly Agree). The questionnaire was previously tested with a PT. Some statements have been clarified and the category to which each item belongs has been added.

#### 4.5. Data Analysis

For the data analysis we used Partial Least Squares Regression (PLSR), using smartPLS v2.0.M3. The PLSR is a statistical method used for Structural Equation Modeling (SEM). These models allow to estimate and explain the dependency relations of several variables. The algorithm reduces several items to a set of constructs and calculates the PLSR for these constructs, defining a model that explains the entire set of relations.

The algorithm starts by estimating the internal consistency of each set of items. It then makes an assessment of the convergent and discriminant validity of the model. For the structural model, the coefficients obtained for each path are interpreted as regression coefficients, by calculating the values of the t-Test through the bootstrapping algorithm, which enables to verify the accuracy of the results suggested by the PLS algorithm. To calculate how well the model fits the proposed relations, the PLS calculates the value of $R^2$ for each dependent construct in the model, thus representing the proportion of variance in the constructs that can be explained by the antecedents.

#### 4.6. Results

##### 4.6.1 Sample Profile

A total of 116 valid and complete answers were collected from this questionnaire, which exceeds the number of minimum answers suggested in the previous section. We can verify that the survey was answered mostly by physiotherapists (62.9%). The majority (80.2%) of participants have a higher education level. 88.8% of participants use the computer at least once a day in their daily lives but only 71.6% do so daily in the course of their professional activity. Most participants (59.5%) also have more than 5 years of professional experience.

##### 4.6.2 Measurement Model Validation

To verify that each item is a good indicator of its construct, it should have a loading greater than 0.5 [14]. Item CF3 was deleted as it did not meet this

criterion. Convergent validity translates the extent to which items are actually related. It is verified by Average Variance Extracted (AVE), whose value must be greater than 0.5 [11, 2]. Item CF4 was removed to complete this step. It was found that the composite reliability of the different latent variables is always above 0.7, as needed [12]. Cronbach's alpha allows you to evaluate the correlation between items of the same construct, ensuring their consistency. This value was greater than 0.7 (recommended in [20]) for all constructs except Ethics, Habit and Hedonic Motivation, which are still reliable [15]. Since the square root of AVE for each construct is greater than the correlation value with the other constructors, the discriminant validity is demonstrated.

#### 4.6.3 Structural Model

**Table 1:** Structural Model

| | Path Coefficient | t Value |
|---|---|---|
| H1 | 0,229 | 2,171* |
| H2a | -0,118 | 2,171 |
| H2b | 0,435 | 5,539** |
| H3a | 0,062 | 0,579 |
| H3b | 0,397 | 5,093** |
| H4 | 0,335 | 3,582** |
| H5 | 0,091 | 1,062 |
| H6 | 0,061 | 0,589 |
| H7 | 0,206 | 2,335* |
| H8 | -0,023 | 0,207 |
| H9a | 0,118 | 0,810 |
| H9b | 0,276 | 2,165* |
| H10 | 0,057 | 0,582 |
| H11 | -0,063 | 0,427 |

* $p < 0{,}05$
** $p < 0{,}001$

The results of the structural model indicate that the intention to use is a function of performance expectancy, facilitating conditions and habit. Therefore, Facilitating Conditions is the construct with the greatest weight. The model thus explains 47.5% of the variance of usage intention.

Although it does not have a direct impact on intention to use, effort expectancy has a negative influence on performance expectancy, representing 18.9% of its variance and thus demonstrating an indirect effect on the usage intention of the systems.

Although the impact of trust on the intention to use the systems is not demonstrated, it was clear that it suffers a positive effect of social influence and a negative effect of privacy concerns, representing 19% of variance in the construct.

#### 4.6.4 Discussion

Looking at the structural model, we conclude that facilitating conditions, that is, the belief of PTs that they have strong technical and organizational conditions for the adoption of these new technologies, is the strongest predictor among the three. PTs then need the support of their organizational structure to apply these innovative products. First, they need to have the necessary resources available in their work station. Secondly, they need to have the technical knowledge or training to use them, ensuring they always have sources of knowledge at their disposal to consult as needed. Finally, the systems must be versatile enough to meet the needs and requirements of the PT's clinical practice.

The second construct with the greatest weight is habit. This means that PTs believe that these systems should become recurrent in their daily practice and would become indispensable for their work.

Finally, the last construct to consider is the performance expectancy, namely the belief of PTs that a markerless motion capture system can substantially improve their daily work and daily activities.

These results allow us to draw several conclusions for the design and distribution of these systems in a clinical context. Briefly, the great responsibility for adopting this equipment is placed on the medical or hospital organization and the training it gives to its workers. The markerless motion capture systems must meet the real and daily needs of PTs, meet their goals, and must be simple to use. Finally, PTs revealed that they believe that these systems will become an integral part of their work.

### 5. ARCADE: From Lab to Clinical Environment

ARCADE is an application developed by Faria [9] that aims to assist PTs in their daily work where they systematically have several patients to attend at the same time, making it impractical to monitor and properly record the performance of all patients. ARCADE has three distinct views: the social, personal and intimate space. When the therapist is with the patient, the metrics and visualizations provide detailed information to accurately evaluate the exercise. When he moves away, the metrics boil down to those essential for the patient to be able to perform the exercise and for the professional, at a distance, to understand if everything goes well.

#### 5.1. Design Guidelines for Clinical Environment

One of the main problems raised from the literature is that, while applications are intended for clinical practice, solutions are always tested in a controlled laboratory setting. Thus, in order to characterize clinical environments, several observations were made. We visited Hospital Garcia da Orta during one morning, Clínica Universitária Egas Moniz for three days and Fisiogaspar during one session.

From these observations and reports from the PTs the following design guides were raised: the

gymnasiums are large spaces loaded with diverse rehab equipment; the number of PTs is much lower than the number of patients, which means that they conduct several sessions simultaneously; the exercises performed are always adapted to the patient's abilities and therapy goals; objectives may depend on number of repetitions, speed, range, space; patients are often left alone to perform the exercises; there are no objective metrics that PTs can take; PTs do not have enough time to record the few metrics they draw from the session.

### 5.2. ARCADE Prototype

ARCADE uses KinectV2 as its markerless motion capture camera. The data is received and processed by Unity3D, where we developed an interactive application, which is used in a tactile tv monitor.

Since the goal of this paper is to evaluate the adoption of the system in a clinical context, some aspects raised by the prior evaluation of ARCADE in the laboratory [9], the adoption study reported in Section 4 and the observations previously reported were taken into account.

#### 5.2.1 Exercises

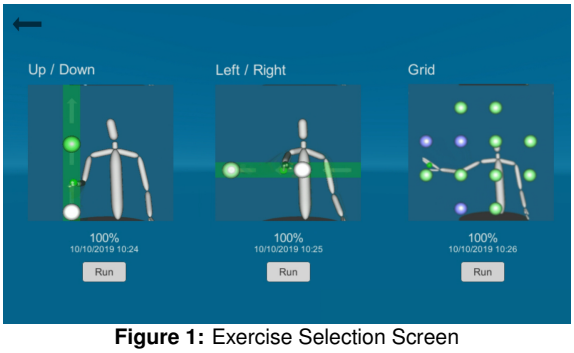


**Figure 1:** Exercise Selection Screen

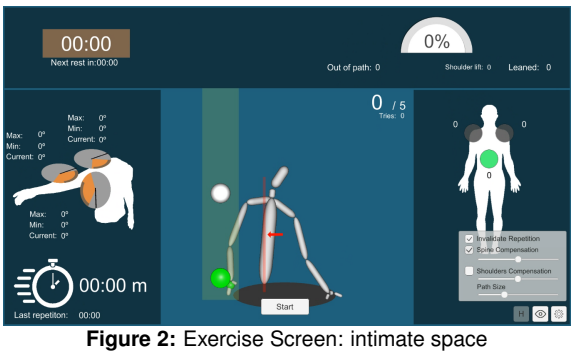


**Figure 2:** Exercise Screen: intimate space

Since it's intended to meet the needs of PTs, three basic exercises, suggested by PTs, were chosen. ARCADE now supports a horizontal movement exercise, a vertical movement exercise, and a grid exercise, where the patient must pass his hand over all points. A preview of these exercises can be seen in Figure 1. Since all exercises need to be adapted to the patient's abilities and the goals that physical therapists have for the sessions, exercise customization options were added. This includes: changing the path's size; changing its position; changing the targets' position; and defining if they want to invalidate a repetition or not in case the patient performs something wrong. These changes allow PTs to customize a standard exercise, meeting all the patients' goals. When the same patient performs an exercise again, the settings of the last execution are reset.

Given that gyms are often very crowded, PTs can now change the viz interface, instead of it being dependent on the distance between the professional and the patient. A preview of the interface aspect while playing an exercise in the intimate space can be seen in Figure 2.

#### 5.2.2 Records

One of the main features added to ARCADE is the ability to store exercise information performed by each patient. This feature seeks to address the scarcity of assessment records that exist in clinical practice. A register and login platform was created and each patient gets his own profile. When someone logs in, a new session record is created, with its associated timestamp. Every time a patient performs an exercise, its results are saved and linked to the corresponding session. PTs can always have access to this data in a proper results screen, where they can see what exercises were performed and when, its performance total time, repetition average time, total number of repetitions, number of the correct and incorrect repetitions and number of movement compensations. They can also add comments to each session record. A preview of this screen can be seen in Figure 3.

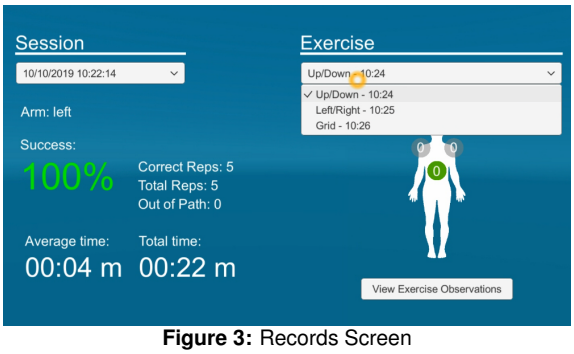


**Figure 3:** Records Screen

### 6. Evaluation

One of the goals for this study was to develop a robust system that would support the needs of PTs in a clinical setting. In order to obtain qualitative and quantitative feedback about the prototype several methods were used.

Before designing the evaluation process, it was necessary to consider which research questions this work needed to answer. The main question is related to the process of adoption and intention to use ARCADE and it is formulated as:

- Do PTs intend to use markerless motion capture systems like ARCADE in their daily clinical practice?

Once this question was answered, others were formulated to assess ARCADE's responsiveness to the needs and goals raised in the observations.

- Do PTs consider that ARCADE would increase their productivity? Under what circumstances?
- Do PTs consider ARCADE an easy-to-use system? If not, what can be improved?
- Are the metrics recorded by ARCADE sufficient for patient assessment?
- What are the main barriers faced using ARCADE on a daily clinical practice?
- Do PTs have the knowledge and resources to use ARCADE?

### 6.1. Methods

The system was evaluated in two different ways: firstly, ARCADE was demonstrated with and evaluated by PSs to get as much feedback as possible; In parallel, it was evaluated by PTs in a clinical context for two weeks.

#### 6.1.1 Evaluation Method with Students

This study was conducted with PSs interns from Escola Superior de Saúde Egas Moniz. We made a demonstration of the ARCADE prototype and asked the participants to always tell what they were seeing and thinking, following the Think Aloud Method. At the end of the demonstration, participants answered a questionnaire with some statements related to some of the UTAUT constructs. This questionnaire had 20 statements on a discrete Likert scale between 1 (strongly disagree) and 7 (strongly agree). Finally, a semi-structured interview was conducted, to better understand the results of the questionnaire and to get as much feedback as possible about ARCADE.

#### 6.1.2 Evaluation Method in a Clinical Setting

To evaluate the facilitators and barriers discovered by PTs in the use of systems such as ARCADE, and to understand the factors that influence their intention to use, the system was installed for ten working days at Clínica Universitária Egas Moniz. On the first day, a demonstration was held with the PTs. At the end of this moment, we told PTs the purpose of this study and that they should use ARCADE when they want and when they think they could benefit from it. Every day PTs were asked to complete a daily questionnaire and, at the end of the two weeks, PTs were asked to answer some questions in a semi-structured interview.

## 7. Results

### 7.1. Evaluation with Students

This study had the participation of 13 PSs, between 19 and 24 years old, from the second (30.8%) and third grades (69.2%). Most of them had never treated upper limb injuries (61.5%).

The Think Aloud method only revealed few small issues about the system's interface. In general, PSs were able to identify and understand all the information displayed in the screens and revealed the knowledge to properly use the system. Regarding comments or general thoughts during the demonstration and in the interviews, there were times when several participants were enthusiastic about the application, its interactivity and ease of use.

In the questionnaires we discovered that the majority of the PSs would use ARCADE in their daily practises. PSs think that ARCADE is a useful and easy-to-use tool that would facilitate their work. They consider they would easily learn how to use it. They also agree that patients would like the system and that they would take advantage from its use. PSs are not concerned about seeing their work being replaced by systems similar to the one presented.

### 7.2. Evaluation in a Clinical Setting

The study included three PTs from Clínica Universitária Egas Moniz and teachers of the Physiotherapy course at Escola Superior de Saúde Egas Moniz. They all have a master degree in Physiotherapy and have over fifteen years of professional experience. Their intervention areas are musculoskeletal physiotherapy (2), neurology (1) and physiotherapy for vestibular (1) and temporomandibular (1) dysfunctions. All of them treat or have already treated upper limb injuries and all of them have used interactive technology, at least once, while performing their professional duties.

During two weeks, the system was used by a PT with two different patients. The PT registered the patients and selected the desired exercises without any difficulty.

The first patient (female) used the system for four days and performed 3 times the vertical movement exercise and 3 times the grid exercise in each session. The PT asked the patient to do all the exercises with a one kilogram dumbbell, as we can see in Figure 4. This ability to add instruments to ARCADE had not been previously tested. Still, the

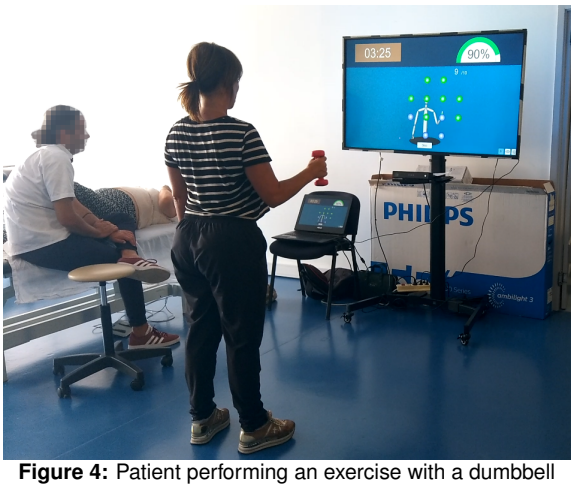

**Figure 4:** Patient performing an exercise with a dumbbell

camera was able to capture the patient's hand positions without any problems. The goal posed by the PT was always to do the exercise in a lower time range. It was possible to observe throughout the sessions an effort of the patient in doing the exercise faster. The average time of use of the system with this patient was twenty minutes per day.

Another female patient, over 80 years old, used ARCADE for the vertical movement exercise. The PT placed a massage bed between the patient and the camera, as shown in the Figure 5. Once again, KinectV2 was able to capture the positions of all relevant joints of the patient's body, even having an obstruction. The patient was not familiar with the technological application and refused, shortly after the beginning of the exercise, to continue, even though the PT gave her the necessary instructions. The PT did not insist that the patient continued to perform the exercises.

**Figure 5:** Patient performing an exercise with the support of a massage bed

In the interviews, PTs said they were pleased with ARCADE and said that, in addition to being easy to use, it is a good complement and aid in their clinical practices. They like to be able to customize the exercises by changing its goals. Despite this, they feel that ARCADE needs to expand the exercise catalog to allow them to perform more complete sessions. As for the feedback given to patients during exercise, PTs find it sufficient but agree that it was beneficial to have a direct indicator of patient's progression comparing the current session with the last session performed. Still, they believe it is a tool that greatly increases the motivation of the patients. As for the metrics used and saved by the app, professionals say they are sufficient and they are able to interpret and relate them in order to assess patients' performance.

Regarding the low adoption of the system, the problem was mainly the lack of patients undergoing upper limb treatment.

### 7.3. Discussion

ARCADE needs more exercises, although the elementary exercises presented served the purpose of this work. By developing a simpler application, it was possible to evaluate which facilitators and barriers were discovered by PTs. Despite this, PTs and PSs agreed that ARCADE is easy to use and revealed to have the necessary technical skills to use it. These results were expected as the whole application design process was a user-centered process with multiple moments of observation, questionnaires, interviews and evaluation [9].

Participants expressed a strong willingness to use the proposed system. The results indicate that participants believe in ARCADE credibility and rely on this solution to let patients autonomously perform physical rehabilitation exercises. Additionally, they recognize the system as an effective tool in assessing patient performance, with useful and accurate metrics that they can interpret and correlate. One patient used the system every day she attended physiotherapy appointments. The physiotherapist indicated that he chose to use ARCADE since the exercise goals converged with the goals set for the patient's sessions and that the patient demonstrated a higher motivation than in conventional therapy.

Physiotherapists confirm that the accuracy level of KinectV2 is sufficient to be able to monitor patients in performing exercises and provide reliable metrics.

The results obtained are very encouraging as they confirm that systems such as ARCADE are very useful for physical rehabilitation practices. In short, participants confirm their desire to use the system (Intention to Use) and acknowledge that the system's performance is positive (Performance Expectancy) and that it is intuitive and easy to use (Effort Expectancy). PTs and PSs are very moti-

vated to include these systems in their daily practices.

### 8. Conclusions

The main objective of this paper was to try to better understand the process of adoption of markerless motion capture systems by PTs in a clinical setting. These systems are useful and effective tools for PTs to be able to improve their interventions, allowing constant feedback about the patients' performance even when they are left alone while performing the exercises.

First, an adoption study was conducted based on the questionnaire proposed by UTAUT. This study gathered 116 responses from PTs and PSs and concludes that 47.5% of the variance in Intention to Use markerless motion capture systems is explained by Performance Expectancy, Facilitating Conditions and Habit. Effort Expectancy also indirectly affects the Intention to Use as it has a negative effect on Performance Expectancy. To the best of our knowledge, this was the first UTAUT-based study about markerless motion capture systems.

We developed ARCADE, a Unity3D application that uses a markerless motion capture camera, KinectV2 for Xbox 360, to conduct upper limb rehabilitation exercises. The system was evaluated using two distinct methods: first, a demonstration was made with PSs, followed by a questionnaire and a semi-structured interview; finally, the system was available for ten working days at the Clínica Universitária Egas Moniz for clinical use. From both methods we can conclude that both PSs and PTs are very motivated to use these applications in their clinical practice. The application was considered simple, easy to use and intuitive and it was not necessary for professionals to have much technical and theoretical knowledge to understand how it works. The proposed camera was considered sufficient for the purpose of the system, while allowing the exercises to be augmented with dumbbells and support platforms. Participants also report that the application can increase patients' motivation to practice physical rehabilitation and it gives them the freedom to let patients perform the exercises on their own. To the best of our knowledge, only Tetteroo [25] has evaluated a physical rehabilitation tool in a clinical context, focusing solely on evaluating feedback.

#### 8.1. Future Work

Above all, ARCADE needs more exercises to be widely adopted, offering exercise variety for more diverse sessions. As verified, the exercises were augmented with dumbbells. This option can be further explored, given that objects can be provided with some intelligence. In addition, ARCADE could offer an option to transform exercises into games or daily activities.

It is also important to have studies that allow understanding of the process of adoption of these systems by patients. As observed, not all patients reacted equally to ARCADE, thus revealing a need to understand what affects their intention to use.

#### 8.2. Limitations

The UTAUT questionnaire is in Portuguese and should therefore not be generalized to other countries or cultures. In addition, the questionnaire was answered by two different categories of public, PTs and PSs, but no distinction was made between the answers. The effects of age or gender on data analysis were also ignored.

As for ARCADE, it has few exercises and focuses exclusively on upper limb rehab. The studies were conducted in a clinic with only three PTs and very few patients. Although it is a good starting point for getting feedback, it needs to be applied on a larger scale. The interviews were conducted with PSs who do not yet fully know the reality of clinical intervention, having only their curricular internships as their experience.

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