Improving Therapeutic Exercises Possibilities Through a Configurable Augmented Reality Motor Rehabilitation Application

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***Abstract*—Augmented Reality applications for motor rehabilitation have been widely explored. However, solutions usually interact with specific predetermined exercises. In this context, this work aimed to develop an AR motor rehabilitation application capable of interacting with a large variety of exercises configured by the therapists according to the patient's needs. For that, Ikapp Line-AR, an AR application, was developed where physiotherapists can configure the therapeutic movement to be played by positioning a set of dots in the appearance order. To evolve different therapeutics needs, Kinect and EMG interaction is enabled. Besides flexibility, this proposal aimed to provide exercise guidance and specific therapeutics adjustments to improve its therapeutic value. A configuration interface was also proposed to perform all these sets. Gamification aspects were included to motivate and engage the patient. User evaluation was performed with ten physiotherapists, which evaluated Ikapp Line-AR's therapeutic value by scaling each feature importance on therapy, and also usability through the System Usability Scale (SUS). Movements configuration possibility, exercise specific configurations, and guidance feedback were the most important features evaluated by the therapists. These results suggest that the proposed solution provides a tool to help the growth of personalized exercise therapy in the AR applications, making possible such solutions to be used with a more significant number of patients and therapy requirements.**

***Index Terms*—Augmented Reality, Rehabilitation, Personalized Exercise Therapy, Electromyography, Guidance, Gamification**

I. Introduction

Nowadays, computing technology has been an exceptional help in many fields of human society. These technologies can help from simple tasks, such as reminders' mobile applications, to operations that are impossible for human execution, such as large numbers of data analysis and interpretations. In the health field is not different, patients' treatment has been modified with technological advances. Looking more specifically at the physiotherapy field, It is an area where digital solutions present vast possibilities. These solutions go from motion analysis tools [1] [2].

Solutions to help and motivate exercise performance are a large field in the physiotherapy area. In order to properly recover a movement, it is necessary to perform exercises several times. This repetitive characteristic stimulated the use of computational tools to motivate and engage the users in the process. In this context, Virtual and Augmented Reality (VR and AR) tools, commonly integrated with gamification aspects, have been widely explored [1] [3] [4].

Besides a large number of motor rehabilitation VR and AR solutions, these applications commonly interact with some specific exercises [5].However, one crucial aspect of the rehabilitation process is the variance of therapeutics needs for each patient. Since each body response is unique, the therapy must be planned and executed according to this specificity [6]. Due to that, some applications developed to improve the therapy end up being used for only a group of patients with a strict type of limitation because they were thought for a specific exercise. To solve these limitations, the development of solutions that evolve a more significant number of therapeutics exercises and specific therapeutics adjustments may improve the use of interactive systems on the physiotherapy routine.

To improve motor rehabilitation interactive solutions applicability, it is also interesting to provide different interactive tools and feedback [7]. Interaction in exercise applications are commonly performed by inertial sensors, such as the

Nintendo Wii Mote [8] or a smartphone, or by RGB-D sensors, such as the Kinect device [9] [10]. These technologies enable interaction by tracking body movements. Alternatively, Electromyography (EMG) is another tool which can be used as an input for exercise applications [11] [12] [13] [14]. This technology is capable of detecting muscle activity, so the system can be controlled according to its contraction level. EMG tools have been widely explored for biofeedback in motor rehabilitation applications since it can improve users' proprioception, and in this way, the quality of the exercise performance [11] [12] [13] [14]. Providing solutions with different input and interaction options can also expand the cases where the application can be used.

Based on that, this work aimed to develop an AR motor rehabilitation application capable of interacting with a large variety of exercises configured by the therapists according to the patient's needs. Since it had the objective to provide tools for different therapeutics needs, Kinect and EMG interaction was enabled. Besides flexibility, this proposal aimed to provide exercise guidance and specific therapeutics adjustments to improve its therapeutic value. Gamification aspects were included to motivate and engage the patient. The final goal is to improve the possibilities of such solutions to be used for the most significant number of patients and therapy requirements as possible.

II. Related Works

Effective rehabilitation requires repetitive and intense practice, which may be boring to the patients. Technologies are being explored, trying to motivate this practice. In particular, research in the fields of computer vision, virtual reality, and augmented reality has given rise to applications in the educational, working, domestic, and leisure environments, with the potential for significant impact on the lives of individuals with a disability [15]. The use of interactive systems and video games as visual feedback interfaces has been demonstrated as a useful interaction approach for rehabilitation assistive methods [16]. These solutions make use of different strategies aiming to motivate and help the patients to complete specific tasks. Some of them can give the professionals a more detailed way to analyze movement performance, muscle activity, and progress for each patient [16].

A. AR guidance in motor rehabilitation

AR is being used in many studies involving motor rehabilitation [5]. A systematic review [17] showed that these AR applications are mainly controlled by specific upper limb exercises, mainly hand interaction, and are commonly integrated with robotic haptic devices for interaction and feedback. In a study developed by Zhang and partner [18], the developed system provides intuitive training interfaces and entertaining through a low-cost data-glove device. The glove is developed by flex sensors and Bluetooth to detect finger movement; there is an AR-based piano game designed with multiple difficulty levels to ensure that patients with different physical conditions can use the system.

In another AR application, named ARkanoidAR [9], movement guidance is provided through a game mechanic similar to the traditional Arkanoid Atari game; it uses this mechanics to engage patients during exercise. The game consists of the player controlling a bar with shoulder flexion. The main objective is to move it to rebound the moving balls in the environment without letting them pass to the player's side. The ARkanoidAR has additional features related to the therapeutic specificity where the therapist can configure movement limits and the type of muscle contraction (e.g., concentric and eccentric), which will be performed during gameplay. Besides these therapeutic configurations, this game enables interaction only by using movements performed at the sagittal plane (the ones that raise the segment in front of the body).

MirrARbilitation [10] is also an AR motor rehabilitation application which provides movement guidance and feedback. It is focused on shoulder abduction exercise. This system also enables some therapeutics configuration, such as movement range of motion and postural control.These controls provide real-time corrective feedback, which improved users' movement quality demonstrated by the increase of success rate (percentage of correct exercises) from 69.02% without the application guidance to 93.73% with the mirrARbilitation feedback. This system also prevented the users from performing the exercises in a completely wrong manner: without the help of the systems, there were users who performed exercises in a completely wrong manner (0% of correct movements), while when using the system guidance the users' improved to performing at least 73.68% of the rehabilitation movements correctly. These results show the importance of providing guidance and corrective feedback in motor rehabilitation applications.

The sleevAR [19] is an intelligent user interface that combines AR feedback and movement guidance to help rehabilitation exercises; It uses projective light on members to guide a patient through a movement. Like the other applications described, sleevAR also provides feedback to inform the wrong executions and shows which body parts need correction; however, there is no specific instruction on how to correct it. They compared the aimed movement pathway with the performed one and found preciser movement performance when using the AR guidance. One limitation of this application is its interactive tool based on infrared marker tracking, which presents high cost and larger setup environments, not viable to clinical routine use [20].

This variety of AR rehabilitation applications are showing the benefits and effectiveness of these solutions to guide and help the exercise performance, not only as a motivational strategy but also as to improve these movement qualities with a correct performance [19] [10]. The therapeutic value of these solutions was also evaluated by therapists, which approved such solutions as a therapeutic tool [9] [19].

B. EMG biofeedback and AR motor rehabilitation

Biofeedback through electromyography is an widely explored strategies for exercise guidance in different rehabilitation fields, including for example pediatrics [11], orthopedics [12], neurology [13] and urology [14]. It sensor to detect muscle activity and return this information to users via visual, auditory, or haptic feedback [21]. It is commonly used to help patients with muscle weakness to train it. When the muscle is weak, its contraction perception by the users - the proprioception - is low. Besides, this weakness can lead to movement compensation, so the user performs the motion using healthy muscles, which is not the aim of the therapy. So, the biofeedback can help them to know when they are activating the muscles required for therapy urology [14] orthopedics [12]. This strategy can also be used when the aim is to avoid muscle use during specific movements that may be causing movements imbalances, by providing user feedback to reduce muscle tension and its activity [12] [14] [21].

The biofeedback strategy is not a therapy itself, but a tool to be integrated and combined with different therapeutics modalities [14]. As described before, AR is also an exercise guidance strategy that aims, besides motivation, to improve user self-perception and the ability to perform the exercises correctly [10]. In this context, the integration of these two strategies can help to improve the therapy.

One example is the RehaBio [21], which integrated EMG biofeedback and AR aiming to provide not only visual feedback for the patient during exercise performance but also evaluation data to the therapists. Another example from the same research group used Transfer Object Game (TOG), Feeding Animal Game (FAG) [22], Ping-Pong Rehab (PPR), and Balloon Collection Rehab (BCR) [23] to guide movement in parallel with the BioGraph Infiniti for biofeedback. Muscle activation feedback is provided by changing muscle area color in the BioGraph Infiniti screen. However, in these three studies, AR and biofeedback work in parallel, the EMG biofeedback is not overlapped in the AR application. They concluded that this integration provided effective rehabilitation for shoulders exercises.

The EMG integration in an AR system can also be used in patients whose range of motion is deficient, however, the muscle activity is present. This combination can use the detected muscle activation to create an illusory movement in AR application, as performed in the ARIS (Augmented Reality based Illusion System) [24]. The patient's perception of motion can stimulate brain activity in a similar way to the mirror therapy, already vastly used for neurological patients [25].

III. Methodology

This work developed, the Ikapp Line-AR, an AR motor rehabilitation application which interacts through body movements recognized using the Kinect v2 sensors and has an optional alternative to provide EMG feedback. Gamification aspects were included to motivate and engage the patient. To develop solutions focused on users' demands, this work followed the Design Thinking methodology, so empathy and ideation step was performed with an interdisciplinary team. Based on that application was developed and further validated with the physiotherapists. The work was approved by the Research Ethics Committee - CEP of the Federal University of Pernambuco (CAAE: 03508918.9.0000.5208) with decision number 3225381

A. Design Thinking Process

The first step of the development was the empathy and ideation process. These processes were performed through an interdisciplinary team, including physiotherapists, biomedical engineering, computer science, and designer professionals. These sections were performed together with physiotherapists to understand better the real needs in their professional routines and what aspects were essential to improve the therapy process. Thereby, It was made use of an ideation methodology known as Brainstorm. In this methodology, each participant was free to suggest ideas from the product and solution, where nobody could judge or give opinions about the given ideas from any participant until the end of the entire process.

After the ideation process, a discussion was realized about the given ideas, and each participant had to vote for the best suggestions based on the following requirements: i. be configurable to different types of therapies; ii. give visual feedback and guidance to the patient; iii. to be moderately easy not to frustrate the patients; iv. to be possible to provide EMG feedback. The best ideas were selected, and the process of development stated based on the final report. The physiotherapists then validated the developed solution. The application and the validation process will be described in the following sections.

B. Ikapp Line-AR

Ikapp Line-AR [1] is an AR application where dot connections induce therapeutics movements. These connections are performed through body tracking interaction using Kinect v2 device and an additional optional EMG sensor. When EMG interaction is activated, a minimum muscle contraction level is required in order for dot connections to happen. Gamification features, such as score and levels, were included to help the motivation aspects of the solution.

Fig. 1. Ikapp Line-AR : Application Interface

The application interface is composed of user self-image, from the RGB camera, around which the dots will appear

[1]https://bit.ly/33Ao2Zl

(Fig. 1). These points locations are planned and configured by the physiotherapists. For better user interaction and entertainment, a trail is drawn where the cursor is moving, providing the visual recording of the path where the patient did the movement to realize the exercise (Fig. 2). The execution of the movement changes this trail color, it means, if the movement is correct, the trail color is changed to green, else if the movement is wrong, the trail color is changed to red (Fig. 3). Besides that, if EMG is being considered, it is incremented the factor of trail color transparency, in other words, the trail is fully opaque if the patient is doing at least the minimum required muscle activity and starts to get transparent as the muscle activity decreases until it becomes fully transparent. This mechanism provides a visual feedback of the movement which is being executed, pushing the patient to correct the movement.

Fig. 2. Feedback for the correct pathway during the exercise

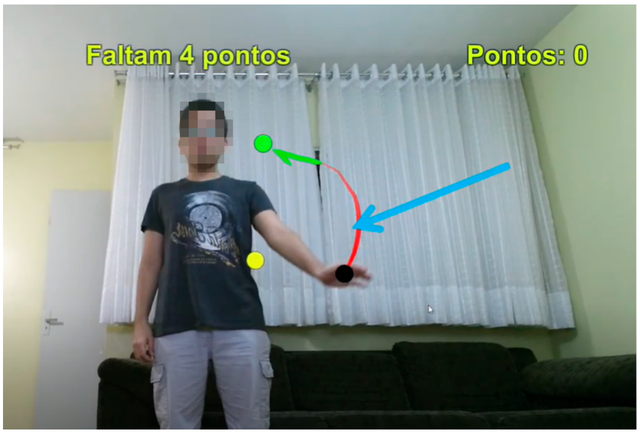

Fig. 3. Feedback for the wrong pathway during the exercise

The application enables a physiotherapist to plan the desired exercise protocol. The therapeutic movements to be performed are defined by setting where the dots which will be connected should appear in relation to the patient position, one by one, according to its appearance order (Fig. 4). For that, each level can be set individually, so each one can correspond to therapeutic exercise, which can be an evolution of the first one, for example, with a higher range of motion, or a completely new movement. The number of repetitions of each level can also be set. Another necessary configuration is the precision required since each patient's coordination level is different; the level of precision in the configured movement can also be chosen. Additional configurations, such as side of exercise and specific movements controls, such as postural compensation tolerance, are available and will be described in the course of this article. The configuration interface will be described in future sections.

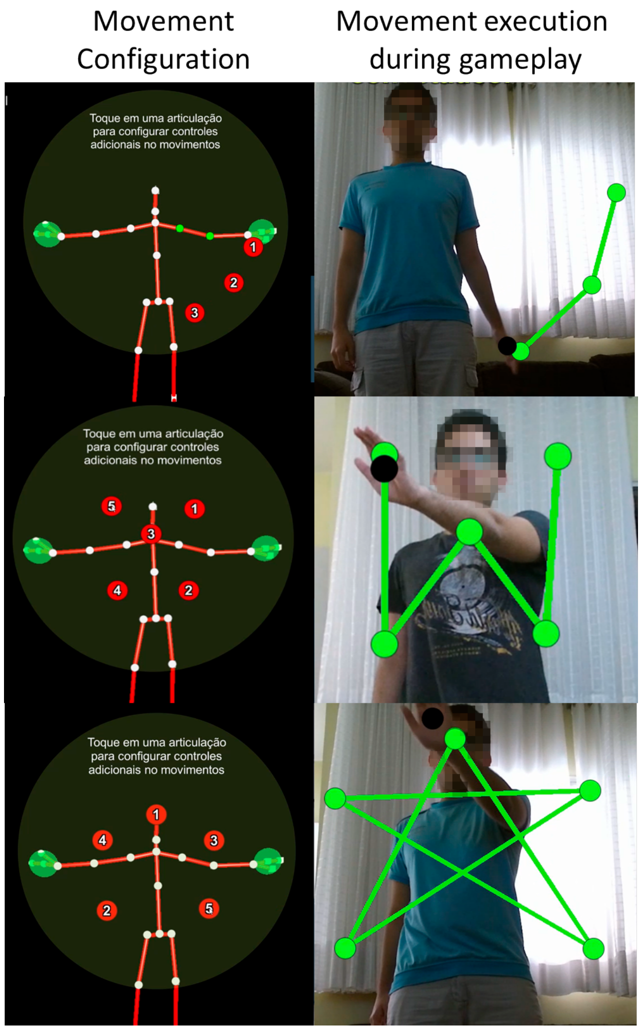

Fig. 4. Therapeutic movements configuration through the dots position and its use appearance in the Ikapp Line-AR gameplay.

Based on these specific movement configurations, the system provides guidance feedback. For example, the red trail described above corresponds (Fig. 3) to the precision set on the configuration. Corrective feedback is also provided; for example, if the therapist sets the elbow angle to have a maximum tolerated angle of 20 degrees if users flex their elbow, guidance feedback will be provided, telling him to ”straighten your elbow” (Fig. 5).

Fig. 5. Corrective feedback: Message indicating user to straighten their elbow

1) Game Engine: To develop the proposed solution, the Unity Engine was used to build the majority part of the application. The Unity, released on July 8, 2005, is a game engine that uses the C# programming language to write scripts and describe the behavior of the scene's components. The choice is due Unity to be one of the most popular Game Engines in the market today, providing fast development results, a large quantity of packages built for it and has an excellent support of the developer community.

2) Body Tracking and Game Interaction: The use of markers and controllers for body tracking is a difficult option due to the different kinds of patient limitations; they should be able to easily interact with the game using the minimum possible quantity of external tools. Considering it, the Kinect v2 was used, providing the tracking of 25 body joints through its sensor. To obtain the Kinect data, It is necessary to use the Official Kinect SDK, which has a Unity Package version, used in this project, to compile Unity Applications based on Kinect.

The project was built over the Sensors Library previously developed by this work research group. The Sensors Library uses in its core the Kinect SDK to get access to Kinect data. This library also offers the option to use the Orbbec Astra. However, during the entire process, the application was developed and tested using the Kinect v2 device. This library provides access to the following functionalities: which and how many joints the Kinect is tracking; the tracking state of each joint, that is, ”Tracking”, ”NotTracking” and ”Inferred”; the joints position, relative to the screen or relative to world space; the angle between two bones; to define a body pose and compare with the tracking body in the sensor and some others.

Once available and configured, It is possible to attribute the joints positions which are being tracked by Kinect Sensor to any Game Object defined in the Unity scene. According to official documentation, a game object in Unity is "...the fundamental objects in Unity that represent characters, props and scenery" [26]. A game object always has a transform representing position and the rotation, specifically, where the position of a joint should be applied.

In the game, it is necessary to apply for the joint position in a game object only two times, once to the cursor that will track the hand, left or right, and another to track the Shoulder Spinner. The update of these positions is done once per frame.

Since Ikapp Line-AR is an AR application, the dots will always be positioned around the user body. Interaction between object and user was performed through collision detection, through Collider Components attached in cursor (hand tracking) and at each instantiated dot.

The Collider Component is also used to analyze the path where the cursor should pass. While the cursor is inside it, the movement trail will be green; otherwise, it will be red because the movement does not match with the expected movement. This path progressively grows as the movement is performed correctly until the patient reaches the goal. After it, the component size and position are updated to analyze the next path.

The additional specific analysis configured by the therapists was performed comparing the current pose with a predefined one using Sensors Library. In this library, all analysis functions and comparisons are built-in. The comparison elements are performed according to the set configuration, such as arm and forearm for the elbow angle or pose.

3) Ikapp Line-AR configuration interface: When starting the Ikapp Line-AR, there are three options in the Main Menu, one to start the game, another to configure game settings, and the last to exit (Fig. 6). The start option is only available if an exercise was previously set.

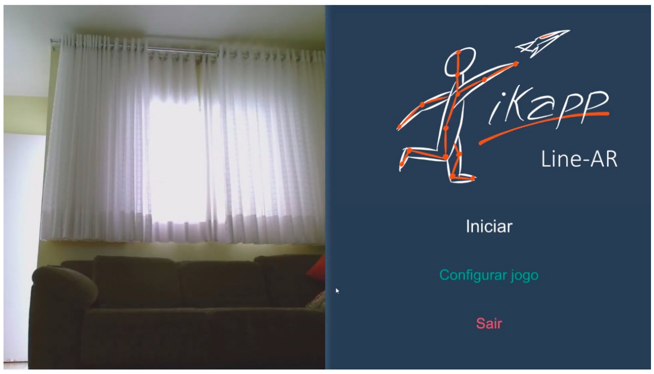

Fig. 6. Ikapp Line-AR Main Menu screen

The configuration interface can be seen in Fig. 7. To configure where dots to be connected should appear on the screen, a Kinect Skeleton at T-Pose representation is used as a reference to offer a spatial perception of elements distribution relative to the body position. So, to configure the therapeutic movement, the physiotherapist can add points by clicking the add point ("adicionar ponto") button and drag them to the desired location in relation to the skeleton. Aiming to preserve the proportion between the configured and gameplay dot position, the Shoulder Spinner is used as a pivot of all these points and is calculated, frame by frame, the percentage of the distance between the shoulder spinner and the maximum that the arm can reach for each point position.

To configure more movements, the new level (“adicionar nível”) button should be used. Users can navigate between levels using the arrows (”<” and ”>”) around the level name in the top center of the screen. A level movement can be done more than once, and It is just to configure at the repetition square (“repetições”), in the right corner, how many times that movement will be repeated. Also, the hand side in which movements should be performed can be changed at the dropdown menu positioned between the level right “¿” and the repetition space.

Specific therapeutics controls can also be configured by interacting with the skeletal representation. By clicking in a specific joint, the physiotherapist can set a range of motion to be limited in a specific plane. These planes are commonly used in the rehabilitation field and already known by the therapists as references to define the biomechanical movements [20]. Postural control and movement precision can also be set by the slide bar (yellow and red respectively) on the right side on the screen.

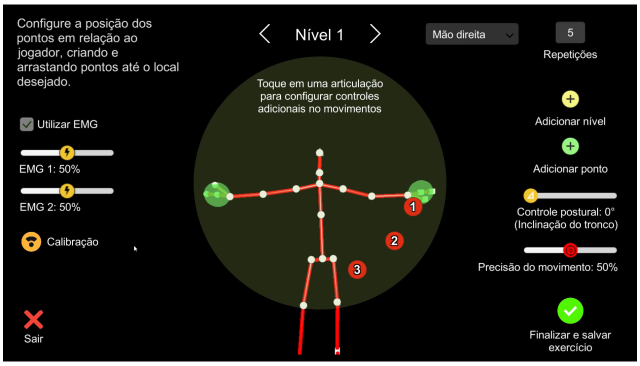

Fig. 7. Ikapp Line-AR configuration interface

C. Electromyography

The Ikapp Line-AR has an integrated two-channel EMG. The game allows users to choose if they want to use a dual-channel EMG to analyze muscle activity. It is optional to provide flexibility to physiotherapists, enabling them to use it according to patient and therapeutic needs. This option can be enabled or disabled at Ikapp Line-AR Settings (Fig. 7, left side of the screen), by default, It is disabled. Once activated, the game mechanics receive these data to improve the interaction. To give visual feedback, a message on the screen will notify the patient when more muscle activity needs to be done (Fig. 8), the patient interaction will not be considered for any point, and the trail color of the cursor will turn proportionally transparent if any of the two EMGs activities are below the configured threshold.

To interact through muscle activity, a process of calibration is required. The calibration screen will appear once the EMG option is selected (Fig. 9). This step asks the user to perform a maximum contraction and will store the minimum and maximum muscle activity levels. With this data, the therapist can define a threshold, a percentage of minimal activity required during the exercise. The application was developed to consider two channels in EMG, this means, to analyze the force of two different muscles. It is possible to define the percentage of force necessary for each EMG, separately, by using the two slides bar at the left of the configuration screen (Fig. 9).

Fig. 8. User feedback for lower muscle activity.

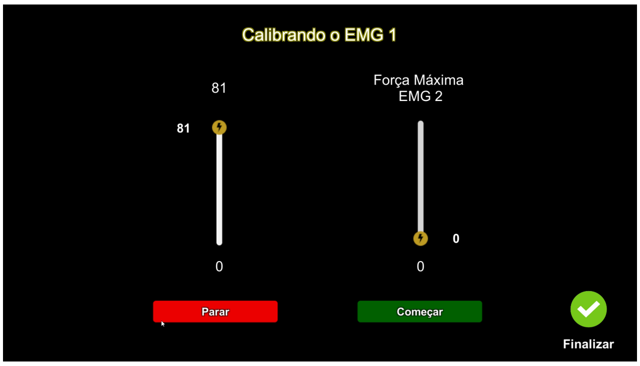

Fig. 9. Electromyography calibration screen

The EMG is composed of two myoelectric channels amplified by two INA 128p with an Arduino Uno board communicating with the computer through a USB port. The communication between Arduino Uno Board and the computational system was developed in C#. The send of data from the communication software to Unity was made by a UDP protocol communication in the localhost machine on port 11000. In the sender, a UDP Client instantiated and opened on the related port to send the data. And in Unity, a UDP Client is instantiated in the same port (11000), to listen and receive the data that is delivered by the EMG device.

D. User test protocol

The user test was planned to evaluate professionals’ opinions on system therapeutic value and usability. Due to the global health situation caused by COVID-19 and the current pandemic and social isolation situation, tests were performed remotely. All test procedures have been approved by the responsible institutional ethics committees (CAAE: 03508918.9.0000.5208), and all participants gave informed consent. For the test, physiotherapists were invited to take part in the study. Once accepted, the procedures were performed via a video call (via Google Meet), where each volunteer agreed to participate and gave their digital consent (through a google Form question). At the beginning of each meeting, users were introduced by an overview of the Ikapp Line-AR aims and characteristics followed by a demo video[2] presentation.

The video presents the Ikapp Line-AR interface, main features, and functionality. Volunteers were free to ask any questions during the experiments, to enable higher comprehension of the system. At the end of explanations and video exhibition, questionnaires were applied through Google Forms. They contain questions about user profiles, including age, gender, professional experience, application first impressions, therapeutic value, and system usability. The therapeutic value was evaluated by asking the user for some specific features ”How important is…”: i. movement and postural feedback correction; ii. gesture control (without requirement any gadget on body); iii. EMG integration; iv. fine adjustments of movement specificity; v. to configure exercises; vi. EMG calibration; vii. movement configuration through dots; viii. to be an Augmented Reality application. These questions were evaluated through a 1 to 5 Likert Scale where 1 is for little importance, and five is for great importance. System usability was evaluated through System Usability Scale (SUS) [27] composed of ten 1 to 5 Likert Scale questions, alternating between positive and negative ones, about users' perceptions of ease of use and system general usability.

E. Data Analysis

The user profile was described using mean and frequency descriptive statistics. The therapeutic data were reported through mean and standard deviation. The SUS score was analyzed following its original computation protocol, resulting in a 0 to 100 final score [27]. SUS usability score is considered to be a minimum of 68 points, lower than that system usability needs to be reviewed.

IV. Results and Discussion

A total of 10 physiotherapists (60% female) participated in the study. The participants aged between 21 and 37 years old and their expertise covers different physiotherapy fields, including neurology, traumatology, orthopedics, pediatrics, clinical, intensive therapy, and sportive ones.

The results for the therapeutic value can be seen in table I. The two highest results were from ”Exercise configurations” and ”Specific movements adjustments”, both with 4.4 scores, followed by the ”Movement configuration through dots”, with 4.2 score. This fact confirms the demands of physiotherapists to have a tool capable of adapting according to the treatment needs and to each patient's limitation levels. The high score of ”Movement configuration through dots”, indicates that dots strategy may be an efficient mechanism to represent and configure the movement that a patient should execute. These results show the benefits of the Ikapp Line-AR solution in the motor rehabilitation requirements to enable the interaction through configurable exercises. It will enable physiotherapists to use the system in a personalized way for each therapeutic need, which has been proven to improve therapy effects and outcomes [28] [29].

Besides the features that improve the possibilities of personalized therapeutic exercises, the guidance ones were also evaluated as high importance. Corrective feedback of movement or posture had a 4.3 score evaluation. This feature improves the system's therapeutic value since it helps patients to perform the exercise correctly. The guidance during the exercises can not only help to improve correct movement execution but also avoid situations where users would perform exercises in a completely wrong manner without noticing [10].

Otherwise, the EMG integration and functionalities presented the lowest score in the evaluation: ”EMG Integration” and ”EMG Calibration” (3.5 and 3.7, respectively). Since the question was the level of importance of each feature, these results may have occurred because not all pathologies affect muscle activity, which makes this feature not useful in these cases. Since the solution was developed in interdisciplinary work with the physiotherapist, these situations were already predicted during development, and it is why the EMG functionality is an optional feature. It can be activated and inactivated according to the physiotherapist's interest and need for each case.

TABLE I
Therapeutic value questionnaire results. The two highest scores at green, intermediates at yellow and the two least evaluated at red.

Importance of...	Score (1 to 5)
Gesture control (No accessories attached)	3.8
Augmented Reality application	3.9
Movement configuration through dots	4.2
Exercise configurations (repetitions, levels and different movements)	4.4
EMG Integration	3.5
EMG Calibration	3.7
Corrective feedback of movement or posture	4.3
Specific movements adjustments (eg. elbow flexion position)	4.4

Ikapp Line-AR usability was evaluated through the SUS questionnaire, which results can be seen in the graphic below in Fig. 10. It obtained 70.25 ± 5 points, reflecting an acceptable level of usability, since the medium average is 68 points [27]. Besides the positive results, it is essential to remember that this evaluation is an expectation of usability and does not represent the real system usability. This fact occurs because the experiments were performed remotely (due to the COVID-19 social isolation), and not with the user's real interaction with the solution. Therefore, some aspects of user experience were not completely tested. Future works with the complete experience and usability test will be performed also evolving different users profiles, including patients.

[2]https://bit.ly/33Ao2Zl

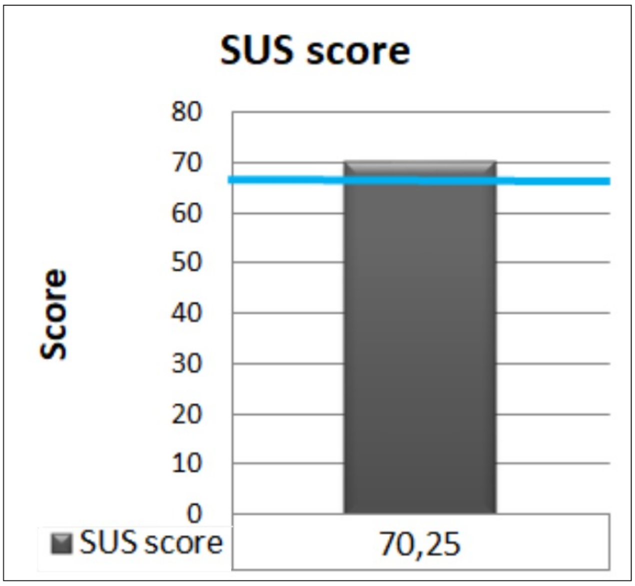

Fig. 10. System Usability Scale (SUS) Score

During the tests, users provided positive feedback. They found that Ikapp Line-AR offers therapeutic possibilities for many kinds of patient limitations and that it can help them a lot. They also enjoyed the visual feedback, wich can induce the correct movement execution.

Physiotherapists also provided constructive suggestions that will be considered in the further improvements of Ikapp Line-AR. One suggestion given by more than one user was to create the option to save an exercise with the name of a patient or a kind of treatment, avoiding the necessity to set the configuration each time the device is initialized. Another suggestion was to allow the movement to be configured with two interaction joints at the same time, to enable the system to offer more complex movements, such as right and left side exercises simultaneously.

V. Conclusion

This work developed the Ikapp Line-AR, an AR motor rehabilitation application that provided a flexible tool to physiotherapists through the use of dots connection mechanics. Through that, they are able to configure the therapeutic exercises according to their patient's needs. Movements specific configurations were the main positive features highlighted by the professionals. The integration with EMG also provides tools for therapists to vary and adapt the therapy when required. This way, the proposed solution provides tools to help the growth of personalized exercise therapy in the AR applications, making possible such solutions to be used with a larger number of patients and therapy requirements as possible. The system's therapeutic value was also improved with exercise guidance and real-time feedback.

Future works include the improvement of Ikapp Line-AR based on users' feedback, such as simultaneously exercises and saving patient exercise profiles. Future experiments with different users' profiles, including patients, will also be performed.

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