Personalising Exergames for the Physical Rehabilitation of Children Affected by Spine Pain

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Abstract: Injuries or illnesses related to the lumbar spine need great clinical care as they are one of the most prevalent medical conditions worldwide. The use of exergames has been widespread in recent years and they have been put forward as a possible solution for motivating patients to perform rehabilitation exercises. However, both customizing and creating them is still a task that requires considerable investment both in time and effort. In this project we present a language with which we have designed a system based on the physical rehabilitation of patients suffering from bone-marrow injuries, which enables customization and generation of exergames. To assess the system, we have designed an experiment with an exergame based on the physical rehabilitation of the lumbar spine. The purpose of this was to assess its understanding and suitability, whose result reveals that the tool is fun, interesting and easy to use. It is hoped that this approach can be used to considerably reduce the complexity of creating new exergames, as well as supporting the physical rehabilitation process of patients with lower back pain.

1 INTRODUCTION

In a systematic analysis (Murray et al., 2012) of the research, called, The Global Burden of Disease 2010, it was estimated that lower back pain is one of the 10 most frequent injuries and illnesses worldwide. It has been calculated that every year between 6.3% and 15.4% of people suffer from lower back pain, while any type of this complaint varies between 1.5% and 36% per year (Hoy et al., 2010). Moreover, in monetary terms, treating lower back pain complaints is an enormous burden on industries and governments, which is even more acute for patients and families dealing with them (Duthey, 2013).

Unfortunately, this type of condition is rather frequent in children and teenagers between 10 and 16 (Jones et al., 2004), who need to perform rehabilitation exercises, which have been recommended by a physiotherapist, at home, and that are essential for reducing the area of pain.

Today, there are some relatively new treatments for physical rehabilitation, the main aim of which are to improve the quality of life of the patients (O'Sullivan et al., 2019). Among these are tele-medicine-based solutions, aimed at making these types of tasks accessible and providing patients with a greater degree of independence (Palacios-Navarro et al., 2015; Lai et al., 2015). There is even a line of research in which gamification-based techniques and serious games are used, in order to create technological solutions which have motivational value to encourage patients to perform more rehabilitation tasks or to enjoy them whilst reducing their pain (Deterding et al., 2011; McCallum, 2012).

However, these approaches are not enough in themselves to tackle two challenges: i) motivating patients to continuously carry out the programme of exercises assigned to them and ii) assessing whether the exercises have been performed correctly. Generally, a child or teenager will perform the exercises at home, but without the necessary motivation, the routine required to do them will fade, and thus the desired therapeutic effect will be lost. Moreover, from the point of view of the physiotherapist, it is advisable to, firstly, have an application or game which encourages the patient to perform the exercises so that he or she can be automatically guided, and to ensure the exercises are carried out correctly. In other words, to provide cus-

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tomized activities according to the patients and their type of illnesses so as to obtain a therapy that is both safe and effective (Pirovano et al., 2016).

In this research, the design, developing and validating a system focused on rehabilitating children and teenagers suffering from some sort of lower back pain, is set out, making use of development kits with advanced artificial intelligence sensors, such as Azure Kinect DK™ device, so as to accurately track skeletons. In this way, the patient naturally interacts with the system, simulating rehabilitation exercises by means of motivating games. The rehabilitation tasks are customized with a language we have defined as Personalised Exergames Language (PEL) which, on the basis of the GL Transmission Format specification (glTF) (Robinet et al., 2014), keep both information about the exergame mechanics, gamification elements and metrics for measuring how the patients are progressing. This information is defined by therapists based on the patient's condition, which is converted into PEL sentences for automatically generating exergames. Therefore, a co-creative approach is established between therapists, patients and developers.

By way of validation, the system has been assessed by 23 potential users, being the main objective to obtain feedback about its understanding and suitability.

The remainder of the article is structured as follows: The section 2 positions our research within the context of other works in the field. Then, the section 3 sets out the system architecture. Subsequently, the section 4 describes the experiment carried out and the results obtained. Finally, in the section 5, the conclusions drawn are described as well as future lines of research.

2 RELATED WORK

At present, there are tools for rehabilitation whose exercises are automatically analysed by machines which use precise skeleton tracking or computer vision techniques. The latter have traditionally been based on using the Kinect device (Webster and Celik, 2014; Da Gama et al., 2015), a low cost hardware solution whose effectiveness has been seen in the field of physical rehabilitation (Clark et al., 2012; Mobini et al., 2014; Mousavi Hondori and Khademi, 2014). Similarly, there are solutions on the market which are orientated at training and fitness, whose aim is to attract specific targets, apart from providing remote rehabilitation from home (Deutsch et al., 2009; Esculier et al., 2012). However, some authors shows scepticism towards this approach, claiming that the lack of customization of these games may make injuries more likely (Sparks et al., 2011).

In light of this issue, various authors have set out a series of considerations to ensure that exergames are both efficient and safe. In (McCallum, 2012), one of the most outstanding proposals is to control the game experience, given that, depending on whether the target user is a child or adult, the original concept of the game may be misinterpreted. A similar approach is presented in (Wiemeyer et al., 2015), which provides recommendations for the optimal design of exergames. To take an example, it identifies postures which ensure patient safety when in rehabilitation, or adapts the game design to the patient characteristics. A slightly different approach, which is presented in (Pirovano et al., 2016), provides a methodology split into four phases for creating and designing efficient and safe therapeutic exergames.

The use of exergames and gamification techniques has also been studied in the literature to assess their effectiveness in the rehabilitation process. A systematic review, shown in (Matallaoui et al., 2017), analyzes different types of systems and their context, the game elements used and the results yielded from them, providing positive outcomes both in patient conduct and their well-being. In a similar vein, the research presented in (González et al., 2018) explores studies on games and gamification applied to physical exercise, which finds positive effects in a reduction in body weight and in encouraging physical exercise. Similarly, the paper (Katajapuu et al., 2017) shows a set of exergames evaluated by a group of thirty participants, which concludes that video games are useful in the physical training of elderly people.

There is also a state of the art angle in which technological solutions orientated at facilitating or automating the generation of exergames is envisaged. For example, the TANGO:H (Tangible Goals:Health) platform (González et al., 2013), has a range of functions and contains a graphics editor to help experts create exercises adapted to patient needs. In this case, it refers to hospitalized children. Similarly, in (Hardy et al., 2015), the StoryTec tool has been envisaged. This was designed to support experts in the field, such as doctors or therapists, so that they can adapt and customize games-based training programmes for elderly and disabled people. In a similar vein, the VirtualGym environment is also worth mentioning (Fernandez-Cervantes et al., 2018), which has been set out as a cooperative framework in which medical professionals design exercise routines which later become games in which an avatar guides the patient during his or her rehabilitation process.

3 ARCHITECTURE

Figure 1 graphically shows the architecture designed for the rehabilitation process for bone-marrow injuries. This approach mainly requires an expert in the field to participate, namely, a therapist, entrusted with assigning an exercises routine to the patient. As can be seen in the figure, the exercises routine is defined by means of data modelling in *.gltf* format extended with our PEL language, which stores all information relating to the exergame. That is, the game dynamics, graphics, gamification elements, and the different metrics by which patient participation can be evaluated. In the subsection 3.1, there is an in-depth explanation on the structure of the language we have defined, so as to provide details in the subsection 3.2 on the translation process for this model in order to automatically generate exergames.

Additionally, this architecture is based on a hardware component for precise skeleton tracking, here we use Azure Kinect DK™, a device developed by Microsoft which includes a RGB (Red, Green and Blue) camera, a depth sensor and several microphones, apart from the software necessary for capturing movements and recognizing voice commands. The capture module is that which interacts with the hardware device in order to obtain the information associated with the position and orientation of the bones that make up the patient skeleton. This module is responsible for filtering the data provided by the device, excluding any information that is not related to the bones in the rehabilitation exercise. For example, if patients have to lie down to exercise their backs, and raise the upper part of their torsos, data related to the lower part of the hip is omitted. Apart from that, the capture module also manages voice recognition, as it enables the voice of the patient to be analysed in order to perform certain tasks, namely, starting a rehabilitation routine or indicating that the activity has finished.

The processing module carries out two specific tasks: i) it evaluates the exercise performed by the patient and ii) it monitors motivation according to the activity. A games scenario by definition in our system is made up of an avatar and a sequence of nodes, called actors, which make up the path a specific part of the patient's body must take. To evaluate the exercise, the module analyses the set of bones that have interacted with the sequence of actors and the order in which this interaction has taken place. In this way, patients are aware of whether they are performing the exercise correctly, as the module shows scores as the activity progresses. Furthermore, it helps to keep them motivated, whether the exercise is being performed correctly or not, since a high score may help maintain the rhythm, or even a low score may help incentivize them to improve.

Finally, the visualization mode is responsible for showing on the screen how the patient is progressing in respect to the task performed. This module is interconnected with the processing module, which provides information in numerical format (score the patient has, percentage of progress for the activity or achievements, amongst other items) in a visually attractive format which can easily be interpreted by the patient in order to capture and maintain their motivation and attention.

3.1 PEL Structure

PEL comes from a higher level specification, popularly known as glTF[1], a relatively new, open for-

[1] https://www.khronos.org/gltf/

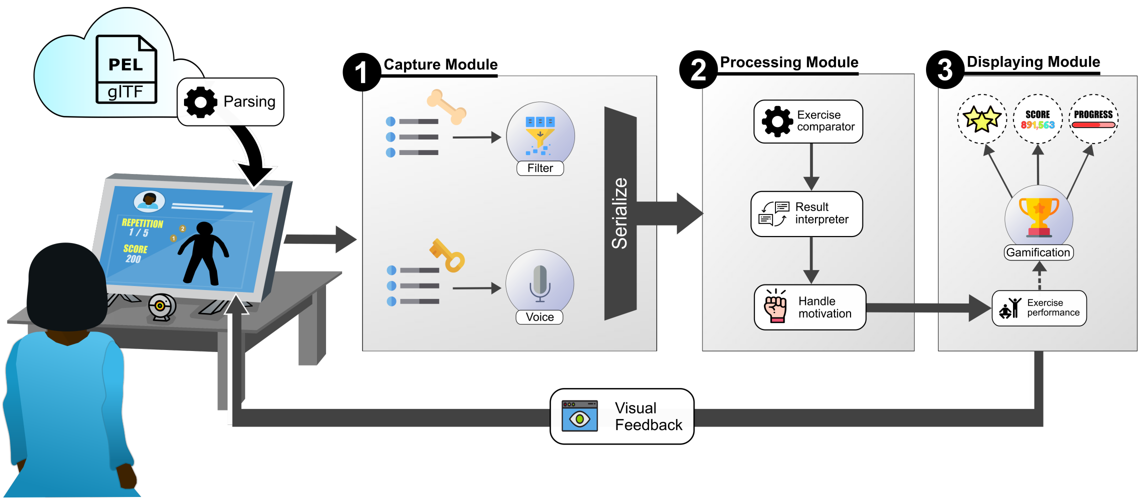

Figure 1: General overview of the proposed architecture for rehabilitation of patient suffering from bone-marrow injuries.

mat, based on the JSON standard, for distributing 3D scenes in an efficient and interoperable way. It was chosen because i) it is an open project, which means certain parts of the product can be freely changed to customize it; ii) it is an efficient and interoperable format; and iii) the extensibility of its data modelling by which new properties can be added which provide new opportunities for improving and building on the specification.

Fundamentally, our language is made up of a series of components that potentially enable tools to be developed, which through parsing, automatically generate games-based exercises focused on rehabilitating patients. The following points briefly summarize the elements which define the nature of an exergame with PEL (see Figure 2):

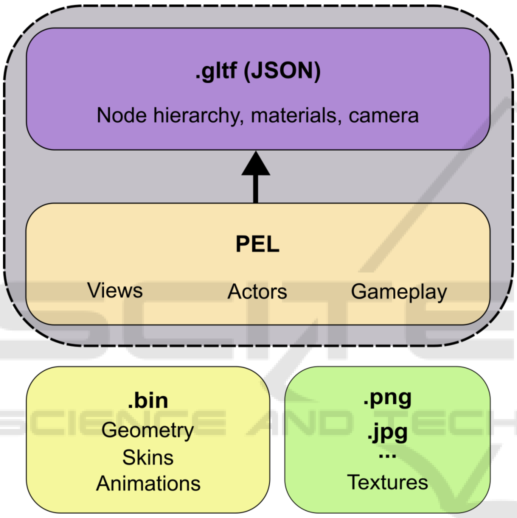

Figure 2: Representation of an exergame structure using glTF extended with PEL language.

- **Views.** Contains three different views which the game is split into. That is, the language envisages a tutorial view, where an avatar, using animation, shows the patient the activity to be carried out; a scene in which the patient performs the activity that has been visualized previously, with movements replicated by the avatar; and finally a view where the results are shown as a result of the actions carried out by the patient.
- **Actors.** They represent the elements of the game that the avatar must interact with. These objects essentially make up a sequence of the activity the patient must perform, with behaviour that may be either static or dynamic. That is, elements that move in a 3D space through animation, or which are just fixed elements suspended over a certain point in the 3D scene. Moreover, these elements provide visual feedback, which in itself, indicates that the node must be or has interacted with the target joint.
- **Gameplay.** Defines the set of actions the user must take to complete a repetition of the exergame. In other words, it specifies the sequence of the actors and the user interaction mode with them. Correct execution of the game mechanics deploys gamification elements to capture, interest and motivate the user, which results in increases the score the patient achieves for each repetition, the progress of the activity or on unblocking achievements, for example.

3.2 Automatic Generation of Exergames

An exergame is automatically generated from a hierarchical analysis of a file with a gltf extension, whose structure is defined by means of the JSON syntax.

This system has been implemented as an application developed with Unity 3D[2] game engine, deployed for Windows and Linux, both of them duly supported by Azure Kinect DK[3]. This application receives the contents of a 3D scenario in the way of a URI (*Uniform Resource Identifier*), which is subsequently analysed by means of parsing technique in order to build the game.

The mechanism for adding gITF extensions by means of the "extras" field have made it possible to create these type of scenarios. All the elements which a 3D scenario is made up of (scene, node, camera, material, animation, etc.) are added in order to provide new functions for highly specific cases.

The process for analysing the "extras" field is integrated into the parsing module, which takes the form of a syntax analyser, based on the gITF implementation, in order to effectively deserialize the elements included in the JSON file. In this field the attributes, which form part of the PEL language, are included to add specific behaviour so as to support the physical rehabilitation process for patients.

To each of the "extras" field, we have added an identifier as a primary property, whose purpose is to help determine the type of behaviour which should be assigned to a node (e.g., `{ "type" : "actor" }`). Therefore, once the object which implements an extensible field is detected, our parsing module identifies the information to be deserialized so that it behaves appropriately when the exergame is running.

[2]https://unity.com/es
[3]https://azure.microsoft.com/es-es/services/kinect-dk/

4 VALIDATION

In order to evaluate the designed system, a quasi-experiment with potential patients has been carried out. The purpose of this was to validate the system in terms of understanding and suitability. The results of such experiment are described and discussed in this section.

4.1 Exergame to Evaluate

The architectural design defined in this paper supports the integration of a wide range of exergames orientated towards different types of injuries, ranging from lower limbs to upper ones.

Taking advantage of this architecture, an exergame was developed to motivate potential patients to perform exercises aimed at the physical rehabilitation of the lumbar spine. The exergame was customized by a therapist, who defined the therapeutic objetive, the trajectory of the rehabilitation movement and the metrics to measure the progress of the patient, being this information translated into PEL sentences to automatically generate the game.

This exercise consists in facing up from a lying down position, raising the upper part of the torso by about 25 cm with knees bent and feet resting on the ground. Patients must maintain this position for 2 seconds and then return to their original position. In essence, the exercise is repeated 5 times, where the satisfactory realization of each one increases their score by 200 points.

Figure 3 shows the different views which make up the exergame designed for the physical rehabilitation of bone-marrow injuries. In (1) there is a screenshot of the tutorial view, where the avatar is seen carrying out the movement, which the patient must replicate later on. The participant view (2) reflects how the patients repeats the movement shown in the previous view, increasing his or her score each time the repetition is performed correctly. Note the spherical blue object (actor), which is used both as a guide for performing the exercise and as a mechanism for determining the stopping conditions in a repetition. Patients can interact with the exergame as PEL is highly flexible and the language is versatile enough to define these situations. In this case, once the head of the avatar collides and remains on the sphere for 2 seconds, the repetition finishes and the score increases. Finally, the results view (3) reflects the indicators entered in PEL language for measuring the exercise performed by the patient.

4.2 Participants and Method

The experiment was carried out by two instructors and some girls from a rhythmic gymnastics club. Twenty-three girls were randomly selected, of whom 20, aged between 11 and 19, agreed to participate in the experience. Of these, 8 suffered from some type of injury, mainly related to the spine, which requires rehabilitation exercises at home. In order to avoid biasing the results (McCambridge et al., 2014) and to motivate their participation (Shull et al., 2007), we explicitly stated at the beginning of the experience the information collected would be treated confidentially and used exclusively for this research. After being informed, girls and their parents gave their consent to

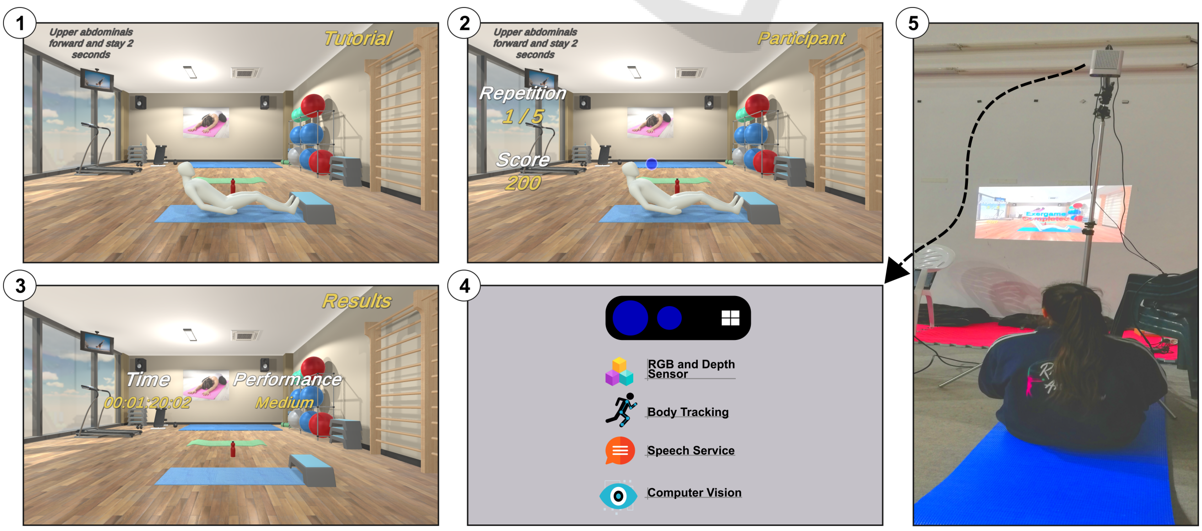

Figure 3: Rehabilitation system in action. (**1**) tutorial view. (**2**) Participation view. (**3**) Result view. (**4**) Features of the Azure Kinect DK™ device. (**5**) User using the system.

use their data.

The quasi-experiment was divided into two phases, conducted in one session of 120 minutes:

- **Phase 1 (Preparation Phase).** One instructor presented the system to all participants for ten minutes. An example of using the system was projected onto the wall so that the girls may understand the explanation.
- **Phase 2 (Development Phase).** Each girl participating individually engaged in two activities: First, they completed the prepared exergame, which required about 2 minutes; then, they filled in a questionnaire, which was provided to them through *One Drive Forms*. These concerned their perception of the activity developed, their understanding and how suitable they thought the tool was.

The exergame, used as an exercise for rehabilitating the spine, was projected onto the wall so that the girls may better visualize their avatar, as well as the gamification elements provided by the system.

The questionnaire consisted in 21 items, shown in Table 1, rated on a five-point Likert scale (1: totally disagree; 5: totally agree) grouped into five blocks or dimensions: *performance subjective ratings*, *cognitive load and effort*, *system utility*, *usefulness of the user interface components* and *TAM-based questionnaire* (abbreviated by TAM). (1) The first dimension (performance subjective ratings), composed of four items, allowed us to measure the subjective perception of the users regarding their performance during the activity, assessing aspects such as their interest during its execution, their commitment to doing it correctly, as well as the user-friendliness of the system. (2) The next block (cognitive load) was formed by four items, inspired by the Cognitive Load Theory (CLT) (Sweller et al., 1998), which allowed us to measure two of the types of cognitive load about the use of a software system: the complexity imposed by the task to be performed (intrinsic load) and the complexity imposed by the use of the software and the interaction devices used during the performance of the task (extraneous load). In addition, two questions were included related to the effort the users had to make to complete the task. (3) The third block consisted in four questions related to certain users' views: preference for the use of this type of systems over face-to-face assistance in rehabilitation centres, the system's game format and finally, whether they considered that its use might improve their motivation and constancy in rehabilitation tasks. (4) In the following block, five items were included in which users had to assess the degree of usefulness of each of the main elements of the application's user interface (virtual representation of the user, number of repetitions, score, etc.). (5) Finally, users completed a questionnaire based on the Technology Acceptance Method (TAM) framework (Davis, 1993), which included four items to measure the perceived user-friendliness, usefulness and intended uses for the system being evaluated.

To speed up the process of filling in the questionnaire, we used three laptops so that girls may do it in parallel once they finished the exergame. There was no time limit for this but, on average, each girl used about 6 minutes to complete the questionnaire. In addition, another instructor was in charge of explaining the meaning of some questions to the youngest girls who requested them.

4.3 Results and Discussion

The results obtained from the data collected, illustrated in Table 1, show that the tool has been very well received in all dimensions. It should be stressed that the activity was more fun (item 1) and interesting (item 2) for those girls who had some injury and, therefore, needed rehabilitation, which seems logical. Moreover, all participants thought they had tried to do the activity well (item 3), they had found the system useful and it had been user-friendly (item 18).

All participants considered that the cognitive load of the activity was not very high (items 5, 8). Furthermore, most of them tried to concentrate on the activity (item 6). However, item 7 received a very high score. This may be because the question was posed in the opposite way to the others. Therefore, the results show inconsistencies; probably because some girls were confused when interpreting the values of the answers.

On the other hand, the injured girls valued the system more useful (items 9, 10) because they were aware of what it meant for them to perform exercises at home (without going to rehab centre). One highly important point to consider is that the system can be motivating (item 11), since one of the disadvantages to rehabilitation for young people is the lack of motivation to do the exercises at home. Perhaps motivation is key to understanding the greater enthusiasm of the injured girls to using the system at home (item 20), as well as to recommending to friends (item 21).

As for, the usefulness of the interface elements (items 13-17), they received positive appraisal with the "score" being the best-rated one (item 15). Apart from this, it is needed to bear in mind that gamification has a crucial role in motivating a patient, especially children.

Table 1: Descriptive statistics of the dimensions evaluated. *Mean and standard deviation are shown (in parentheses).

Dimension	Item	Mean		Mode	
		Injured	Not Injured	Injured	Not Injured
Activity Perception	1. This activity has been fun for me.	**5.00** (0.00)*	4.33 (0.65)*	5	4
	2. I found this activity interesting.	**4.88** (0.35)*	4.75 (0.62)*	5	5
	3. I have worked to do it well.	4.88 (0.35)*	4.92 (0.29)*	5	5
	4. It's been easy for me to learn how to use this system.	4.88 (0.35)*	4.83 (0.39)*	5	5
Cognitive Load	5. The activity required a lot of concentration.	3.00 (0.76)*	3.00 (1.48)*	3	3
	6. I've been very concentrated during the activity.	3.75 (0.89)*	**4.17** (1.03)*	3	3
	7. I've had to work pretty hard to get the activity done.	3.13 (1.36)*	**2.17** (1.27)*	4	1
	8. I have found difficult to perform the rehabilitation exercise using this system.	**1.25** (0.53)*	1.50 (0.45)*	2	1
Utility	9. I'd rather use this system at home than have to go to a rehab centre.	**4.13** (1.13)*	4.00 (1.54)*	5	5
	10. This system would make me more consistent in performing the exercises at home.	**4.75** (0.46)*	4.25 (1.06)*	5	5
	11. I believe that using this system to do rehabilitation exercises can be motivating.	**5.00** (0.00)*	4.67 (0.49)*	5	5
	12. I like the application has the format of a game.	4.50 (1.41)*	**5.00** (0.00)*	5	5
Interface Elements	13. The design of the avatar is appropriate.	**4.88** (0.35)*	4.42 (1.24)*	5	5
	14. The information about the repetitions is useful.	4.50 (1.41)*	4.58 (1.00)*	5	5
	15. I like to get score every time I perform a good exercise.	**5.00** (0.00)*	4.58 (0.79)*	5	5
	16. The route composed of spheres helps to perform the exercises.	**4.88** (0.35)*	4.58 (1.16)*	5	5
	17. The gym has immersed me in a rehabilitation environment.	**4.88** (0.35)*	4.75 (0.45)*	5	5
TAM	18. This system is easy to use.	4.88 (0.35)*	4.92 (0.29)*	5	5
	19. Using this system could help me in performing the rehabilitation exercises.	**5.00** (0.00)*	4.83 (0.39)*	5	5
	20. If I could borrow this system, I would use it at home.	5.00 (0.00)*	5.00 (0.00)*	5	5
	21. I'd recommend my friends to use this system to do the exercises at home.	**5.00** (0.00)*	4.83 (0.39)*	5	5

Table 2: Significant correlations among items (*:p<0.05; **:p<0.01).

	Item 5	Item 10	Item 11	Item 14	Item 15	Item 16	Item 17
Item 1			**.457***				
Item 2	**.468***	**.509***					**.498***
Item 6		**.584****					**.427***
Item 9		**.520***					
Item 10							**.634****
Item 11				**.442***	**.824****	**.498***	**.688****

We also have studied the existence of correlations among items using the Kendall tau-b correlation coefficient, a non-parametric measure association as the variables do not follow a normal distribution. We have obtained some interesting findings, shown in Table 2. The positive correlations between item 1 and item 11 reflect that fun and motivation are closely related factors. The correlation between item 2 and item 5 shows that the greater the interest in the activity, the greater the concentration of girls on their performance. Correlations between item 10 and items 2, 6 and 9 indicate that the idea of having this system at home makes them be more motivated to carry out rehabilitation activities. On the other hand, the positive correlations among item 11 and items 14, 15, 16 and 17, indicate that interface elements contribute to motivate the girls to do their rehabilitation exercises. The absence of correlation with the item related to the avatar (item 13) can give us some extra information in the sense that its appearance should be adapted to the user. Finally, the positive correlations among item 17 and items 2, 6, 10 and 11 seem to indicate that the interface contributes to capture the user's interest. All of these correlations can be observed graphically in Figure 4, grouped into three categories: activity perception, usefulness, interface.

4.4 Limitations

This pilot experience presents several threats to internal and external validity (Shadish et al., 2002) that might have influenced our results.

- *Construct Validity*. Some items (5, 7, and 8) were presented in a negative way respecting the others, what has led to a confusion in the answers. This should be taken into account in future experiments to avoid erroneous answers.
- *Statistical Conclusion Validity*. Given the limited power of the sample because of its size and its domain, our data exploration has consisted in a statistical description and a basic correlation analysis among items. A deeper study should be performed in future experiments in order to contrast answers provided by different groups of participants.
- *Internal Validity*. Although quasi-experiments avoid most of the threats to internal validity that arise in other kind of experiments (Bärnighausen et al., 2017), one limitation is related to the interpretation of the results, since it is necessary to consider the possibility that they can be influenced by other factors not taken into account (Cook and Campbell, 1986). For example, the 5 value has been the most frequent one assigned in the questionnaire, which seems to indicate that girls, especially the youngest, were not very clear about the difference between the range of values. Furthermore, since rhythmic gymnastics is a sport that demands a high level of perfection, girls may be influenced, unconsciously, by this level and have thought that the only value which reflects a positive evaluation was the highest. This factor should be taken into account in subsequent research experiments.
- *External Validity*. The sample is not representative for the general population. Besides, data collected in a gymnastics class may not be generalized to other educational scenarios as they are inevitably subjected to bias and non-bias systematic experimental measurement errors. Moreover, although we have considered a generic research hypothesis, its empirical approach has forced us to focus on a concrete context and with a specific tool. Therefore, the replication of this study in other contexts and with other users remains open as an important future working line.

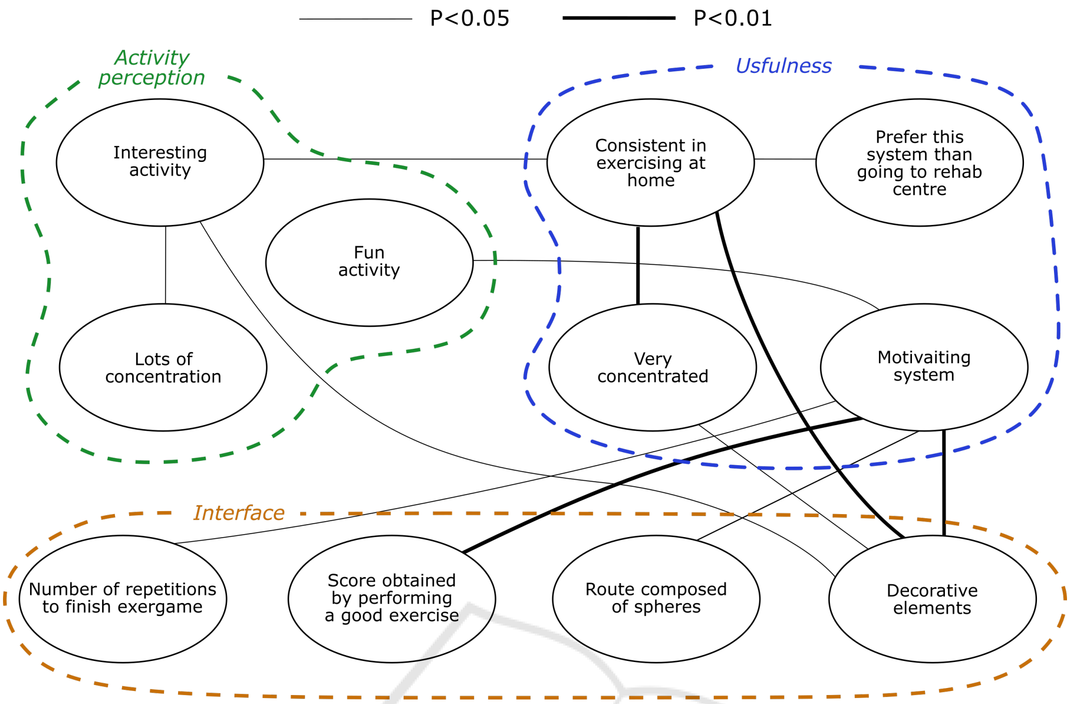

Figure 4: Correlation between variables grouped into activity perception, usefulness and interface.

5 CONCLUSIONS

In this article a system is designed to rehabilitate children and teenagers suffering from lower back pain. The rehabilitation tasks are customized by a high level language called PEL, based on JSON standard, that extends in the glTF specification. The objective of the language in this research is aimed at rehabilitating patients with bone-marrow injuries, although the nature of the language makes it possible be extrapolated to other rehabilitation contexts. The exergames are first designed by therapists, who define the therapeutic objective, the trajectory of the rehabilitation movement and the metrics to measure the patient's progress, all based on his or her conditions. Then, developers translate this information into PEL sentences for automatically generating the exergames by means of parsing process.

This article also includes a preliminary experiment with potential patients to evaluate the system in terms of understanding and suitability. To do this, an exergame was developed to motivate the potential patients to perform exercises aimed at the physical rehabilitation of the lumbar spine. From a general point of view, most participants perceived the tool as an excellent starting point to facilitate the process of patient rehabilitation, considering it fun, interesting, and easy to use.

As future lines of research, we can stress the need to work on two core topics: (1) developing a system or module that is capable of informing the therapist, by way of notifications, on how children or teenagers are progressing, and (2) constructing a visual tool to help therapists graphically set the parameters, which define the dynamics of an exergame, translating the visual definition into PEL sentences.

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