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App-Mohedo®: A mobile app for the management of chronic pelvic pain. A design and development study

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A B S T R A C T

Background: Chronic Pelvic Pain (CPP) has been described as a public health priority worldwide, and it is among the most prevalent and costly healthcare problems. Graded motor imagery (GMI) is a therapeutic tool that has been successfully used to improve pain in several chronic conditions. GMI therapy is divided into three stages: laterality training (LRJT, Left Right Judgement Task), imagined movements, and mirror therapy. No tool that allows working with LRJT in pelvic floor has been developed to date.

Objective: This research aims to describe the process followed for the development of a highly usable, multi-language and multi-platform mobile application using GMI with LRJT to improve the treatment of patients with CPP. In addition, this will require achieving two other goals: firstly, to generate 550 pelvic floor images and, subsequently, to carry out an empirical study to objectively classify them into different difficulty levels of. This will allow the app to properly organize and plan the different therapy sessions to be followed by each patient.

Methodology: For the design, evaluation and development of the app, an open methodology of user-centered design (MPIu + a) was applied. Furthermore, to classify and establish the pelvic floor images of the app in different difficulty levels, an observational, cross-sectional study was conducted with 132 volunteers through non-probabilistic sampling.

Results: On one hand, applying MPIu+a, a total of 5 phases were required to generate an easy-to-use mobile application. On the other hand, the 550 pelvic floor images were classified into 3 difficulty levels (based on the percentage of correct answers and response time used by the participants in the classification process of each image): Level 1 (191 images with Accuracy = 100 % and RT = [0–2.5] seconds); Level 2 (208 images with Accuracy = 75–100 % and RT = [2.5–5] seconds); and Level 3 (151 images with Accuracy = 50–75 % and RT > 5 s).

Conclusion: App-Mohedo® is the first multi-platform, multi-language and easy-to-use mobile application that, through GMI with LRJT, and with an adequate bank of images classified into three levels of difficulty, can be used as a complementary therapeutic tool in the treatment of patients with CPP. This work can also serve as an example, model or guide when applying a user-centered methodology, as MPIu + a, to the development of other apps, especially in the field of health.

1. Introduction

Chronic Pelvic Pain (CPP) has been described as a public health priority worldwide, and it is among the most prevalent and costly healthcare problems [1,2], associated with an important decrease of quality of life and with an increase of morbidity and mortality [3,4]. It is estimated that the increased incidence of non-communicable chronic diseases will cause an associated rise in the prevalence of disability, accounting for 75 % of all deaths by 2030, and thereby creating the most significant public health problem of the 21st century [5].

CPP is defined as the "chronic or persistent pain that is perceived in the structures related to the pelvis of men or women, unrelated to a clear pathology". It often co-exists with symptoms that suggest a dysfunction of the lower urinary, sexual or intestinal tract, or a gynecological or pelvic floor dysfunction, and, when associated with negative cognitive, behavioral, sexual and emotional consequences, it is known as CPP

Abbreviations: **CP**, **Chronic Pain**; **CPP**, **Chronic Pelvic Pain**; **CNS**, **Central Nervous System**; **GMI**, **Graded Motor Imagery**; **iMI**, **Implicit Motor Imagery**; **LRJT**, **Left/Right Judgement Task**; **MPIu+a**, **Processing model of usability and accessibility engineering**; **RT**, **Response Time**; **UI**, **User Interface**; **UX**, **User Experience**.

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syndrome [3].

Chronic Pain induces structural and functional changes in the motor cortex that could partly explain changes in motor control and affect muscle activation. Regarding the affective components, some studies have reported that patients with chronic pain show high levels of neural activation in the secondary somatosensory cortex, anterior cingulate cortex, insular cortex, and amygdala. These findings may reflect the altered peripheral sensory transmission of the modified afferent sensory stimuli and may be a result of the plasticity of the sensory representation of the body and perceptual changes [6–9].

Graded motor imagery (GMI), created by G. Lorimer Moseley and David S. Butler [10] during the first decade of the 21st century, is a therapeutic tool that, assuming the association between chronic pain and the interruption of the cortically-maintained body scheme, has been successfully used in some chronic conditions, such as complex regional pain syndrome [11], phantom limb syndrome [12] and chronic lumbar pain [13–15], indicating that it could be used as a complementary tool in CPP.

The aim of GMI is to facilitate sensory and motor cortex reorganization, which can be altered in patients with CP. GMI therapy is divided into three stages: laterality training, imagined movements, and mirror therapy [6]. Initially, GMI uses Implicit Motor Imagery (iMI), where one of the procedures used is the laterality task or discrimination (LRJT, Left Right Judgement Task) [16]. This stage assesses the capacity of the individual to evaluate whether the body image observed belongs to the right or left side of the body. During this task, both accuracy (number of correct answers) and response time (time used to provide the right answer) are analyzed, since these two parameters are potentially altered in a large number of chronic conditions, both acute and chronic [17]. In a recent study, significant differences were found between PPC patients and healthy subjects: In the laterality task with pelvic floor images, the patients with CPP made more mistakes than the healthy individuals [18].

The increasing use of the internet and mobile devices has led to a growing interest in managing chronic pain through web-based (eHealth) and mobile applications [19,20]. Evidence indicates that apps have been successful in fostering self-management in other chronic conditions like diabetes [21], asthma [22], surgery [23], obesity [24], persistent pain [25], or colorectal [26], vascular [27] and urology management [28].

Pain apps have been generally classified to (1) provide general information on pain, including symptom identification and planning treatments, (2) track daily symptoms such as pain intensity, mood, daily activity, and medications, and (3) provide information on self-management strategies. To Chronic Pain, for example, there are some Apps (Curable, PainScale-Pain Diary and Coach, SuperBetter, Headspace, etc.) [25,29] to foster self-management of pain, self-monitoring of symptoms and self-tailoring of strategies.

However, only one application was developed, Recognise App [30], which, focusing on the first phase of GMI, accurately measures the speed and accuracy of making left/right discrimination judgements in painful conditions; this App is only available for the hand [31], foot [32], back [17], neck [30], shoulder [33] and knee [10], but not for the pelvic floor. Furthermore, to date, there is no application that uses and applies iMI and LRJT to the pelvic floor.

Encouraged by the results obtained in the use of GMI and the mentioned app in other chronic diseases, and in view of the need to find complementary tools that improve the current therapeutic propositions in CPP, we proposed the initiative of creating a multi-platform tool (app) that allows working with GMI (specifically iMI with LRJT) in chronic diseases of the pelvic floor.

The main goal of this work is to describe the iterative and user-centered process applied to the development of App-Mohedo®, a usable, multi-language and multi-platform app, which uses LRJT to improve the treatment of chronic pelvic pain conditions. This development will also require, on the one hand, generating the 550 pelvic floor images that will initially make up the main content of the app, and, on the other, carrying out the empirical study that allows them to be objectively classified into different levels of difficulty. This will be necessary to be able to properly organize the therapy that each patient must carry out with the app. We also hope that our work serves as an example, model or guide when applying the MPIu + a user-centered design methodology to the development of other apps, especially in the field of health.

2. Methods

Rehabilitation researchers, the *software development team*, and *stakeholders* (people with CPP) were involved in a collaborative, iterative and user-centered software development process.

Specifically, it was decided to apply *MPIu + a* (processing model of usability and accessibility engineering) [34–36] (Fig. 1). This *user-centered design methodology* integrates and links the methodology and formalisms of software engineering with those of usability and accessibility, and it is consistent with and follows the standards of User-Centered Design (ISO 9241–210) [37]. Moreover, this model does not have a linear or restrictive sense but promotes its free application. Therefore, the specific requirements of the system, the particularities of the users, and the results obtained in the prototyping process will determine the number of iterations to be performed and how they must be performed. These aspects are specified in a further section.

The rehabilitation team included a group of 3 clinical researchers who provided expertise for individuals with pelvic floor disorders, specifically in CPP, for the purposes of this project. These clinicians presented their idea and requirements to the computer technicians and users, exploring with them a design that responded to the real needs of everyone. The *software development team* was composed of 1 designer, 1 software developer, and 2 usability experts. They provided information early on about the characteristics and development pipeline and phases of the methodology to follow. Three individuals with CPP were included as *stakeholders and end users*, and collaborated with the two teams throughout the process, mainly in prototyping and interface evaluation tasks.

On the basis of the objectives outlined, prototypes were developed, which went through scoping iterations, with feedback from stakeholders and end users. We iteratively refined the app prototypes to meet the end user's needs, while remaining true to the goals of the project. All team members contributed to the design ideas, explained which aspects of mobile interfaces, functions, and tasks they found important or

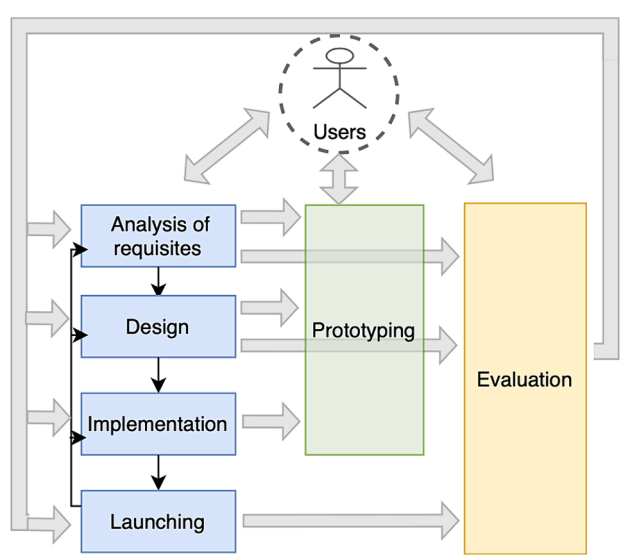

Fig. 1. Process model of usability and accessibility engineering (MPIu + a), User-centered design methodology applied to the development of AppMohedo.

necessary, and provided feedback regarding the interfaces.

2.1. App prototyping (phases 1–3)

Following the considerations of the model (MPIu + a), which presided the design of both the user interface (UI) and the user experience (UX), Fig. 2 summarizes the stages and steps carried out to, subsequently, develop them in further detail.

2.1.1. Phase 1: Planning and requisites analysis

The first step was to describe and specify the methodology to be applied to the development of the project, and then we identified and analyzed the main *goals*, *requirements,* and *cases of use*.

Our primary *objective* was to develop a web-based app that would benefit both patients and clinicians. On the one hand, we aimed to provide patients with access to a trusted source of health information and a complementary rehabilitation strategy that they could use to optimize their pain. We also wanted patients to have a tool that would help them self-monitor their health. In addition, we needed to create a resource that rehabilitation clinicians could use in the management of their patients to better manage their chronic pelvic pain, as well as to access the data of their patients and have recorded variables that allow them to conduct future research work.

In this phase, we established the main *functions* that the software should include, which are summarized in the *cases of use* diagram in Fig. 3: the registration of the user in the app, the access to the system (login), the gathering of information related to the theoretical foundations that justify the use of the app, and, obviously, the realization of therapy sessions, along with the feedback or results that should be shown to the user once said session is over, in addition to the possibility (for both the patient and his/her therapist) of verifying the data of previous sessions. Given the specific orientation of the app in the field of health, and the pelvic-perineal specialty at which it is aimed, an open user profile is suggested, in terms of age and technological competencies.

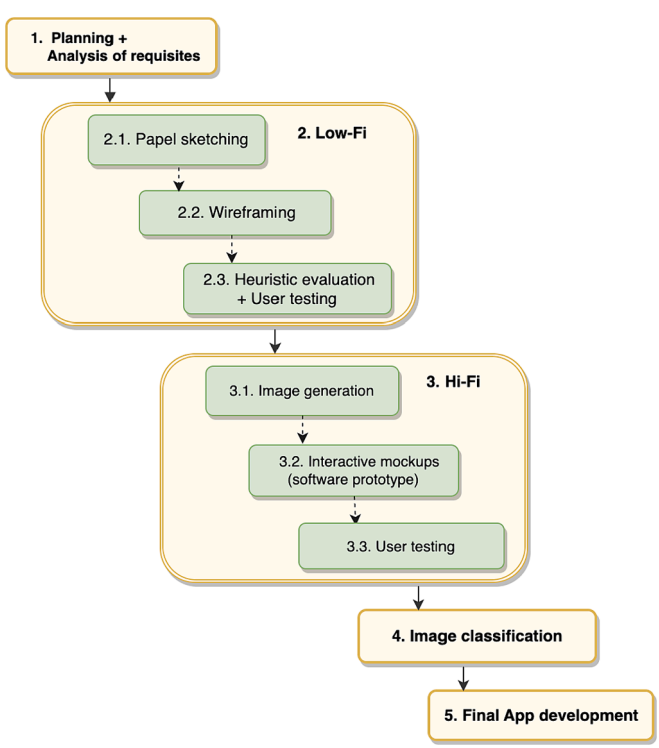

Fig. 2. Main phases and steps of the App-Mohedo development, resulting in the application of the MPIu + a methodology.

2.1.2. Phase 2: Low fidelity prototyping

Once the previous phase is over, a Low Fidelity (low-fi) prototyping and evaluation process was carried out, highlighting the following steps:

2.1.2.1. Sketching. Through drawing and sketch design, we captured the basic objectives and requirements that were described in the previous phase. We started by designing the sketches related to the main task: carrying out a therapy session through image laterality discrimination (Fig. 4). Then, we sketched the rest of the operations that the user could have to conduct before or after such main task.

These low-fi prototypes, which are rapidly developed at a low cost, helped the entire team to identify requirements that had not been initially identified, as well as to evaluate several alternative design concepts and options. Furthermore, both the users and the rehabilitation team, since they were aware of how easily they could make changes, as well as of their low cost (paper sketches), felt more comfortable and freer to give their opinion and propose changes.

2.1.2.2. Wireframing. After discussing the main ideas presented in paper in the previous step, and based on the sketches selected, the corresponding wireframes were carried out (Fig. 5). These two-dimensional illustrations of interface screens specifically focus on space allocation and prioritization of content, functionalities available, and intended behaviors, but without style, color, or graphics.

2.1.2.3. Low-fi prototypes evaluation. In the next step, 2 usability experts performed a *heuristic evaluation* of the wireframes, with the aim of analyzing the conformity of the interface with some recognized recommendations and principles of usability ("heuristics"). Complementarily, a *user testing* process with 3 users was also carried out. The results, after being discussed and analyzed by the entire team, were considered for the following prototyping phase of higher fidelity.

2.1.3. Phase 3: High fidelity prototyping

2.1.3.1. Image generation. To advance in the prototyping process, we generated the main content of the system: the *images* of pelvic floor required to carry out the therapy sessions. To this end, and after the recruitment of volunteers through social networks, who signed an informed consent form and gave their image to the study, a total of 10 volunteers (5 women and 5 men with different BMI) performed 10 photoshoots with an image professional. A total of 550 images were obtained, which subsequently required 3 sessions of photo editing, in order to define the spatial laterality of the pelvic floor images as right or left.

2.1.3.2. Interactive mockups design. After analyzing and evaluating the wireframes that correspond to the interface of the user, another step was made in the prototyping process, considering and incorporating total interactivity, visual aspects, colors, real content (the 550 images of pelvic floor for both sexes), etc.

To develop this *high fidelity software prototype* (or *interactive mockups*), we used the prototyping tool of IONIC [38]. Since they have a simulated functionality and a visual appearance that is more defined than that of the wireframes, these prototypes are already adequate to evaluate the experience of the users when interacting with them, which was carried out through the empirical study conducted in the following step.

2.1.3.3. User testing. This empirical study involved ten volunteer participants (n = 10). There were 6 females and 4 males, with a mean age of 49 years (SD=± 5). After signing the corresponding informed consent, all participants performed the same task, which involved registering oneself in the app, checking the fundamentals of the therapy, the realization of at least 3 therapy sessions (in which they had to classify as "right" or "left" the pelvic floor images that appeared, based on whether

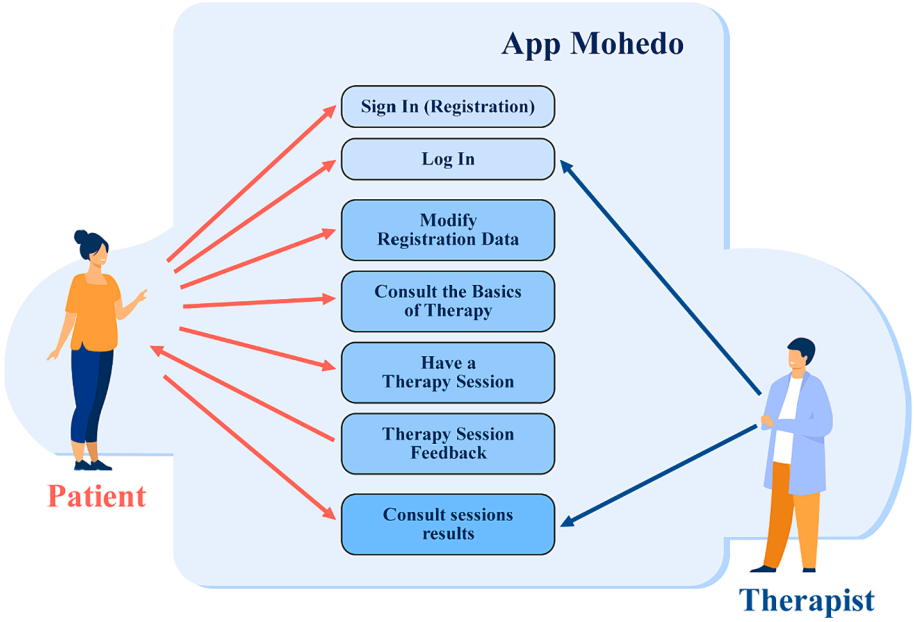

Fig. 3. Main cases of use of *App-Mohedo.*

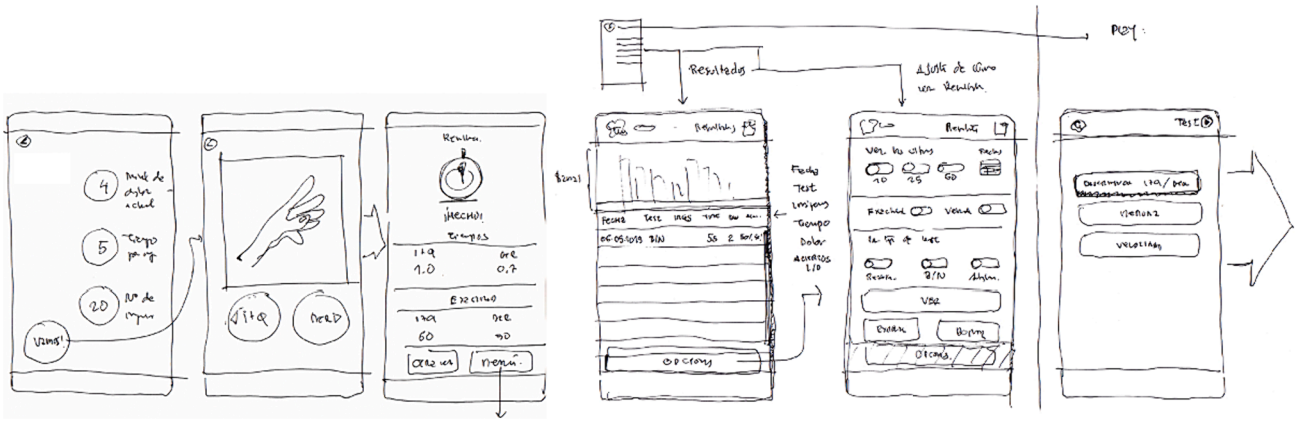

Fig. 4. Some *sketches* resulting from the initial phase of low-fi paper prototyping.

they corresponded to the right or left side of the body, respectively), and, lastly, checking the results.

The *Thinking Aloud* technique was applied, asking the users to tell the member of the team about their thoughts, feelings, and opinions, both negative and positive, regarding the interface and its use, gathering such information.

The results of this user testing were considered for the final development of the app and, although they are detailed in the corresponding results section, it is necessary to point out that one of the common aspects in this stage was the one related to the content of the therapy. In this regard, it was observed that the user required an excessive amount of time to identify certain images, which made us consider the need to classify such content by difficulty levels and, therefore, to include an intermediate study in the development process, which is detailed below.

2.2. App content development: Images classification results (phase 4)

Based on the results of the previous evaluation process, it was necessary to establish difficulty levels that would allow the patient (end user) to progress in the training of the laterality task, understanding from the beginning that those images showing a part of the lower limb (widely represented in the cortex) could make the task easier compared to those images that showed only genitalia (represented in the cortex, although in lower proportion).

We needed to establish some reference or normative values in healthy population that would allow us to classify such images into different difficulty levels, for App-Mohedo®, based on the analysis of the percentage of correct-wrong answers and the time required to complete the task, through their visualization (and classification) by healthy subjects.

To this end, we partially developed the app (a simplified web version) and used it to such end. The frontend was programmed using IONIC, and the backend or engine of the web application was programmed with Laravel [39], which was complemented with Angular JS (JavaScript). Once deployed and put in production in an Internet server (in web mode only), we had the necessary functionalities to use it in the present study.

Then, an observational, cross-sectional study with non-probabilistic sampling was conducted to assess the ability to identify and discriminate pelvic floor images among university students. The design followed the international recommendations for Strengthening the Reporting of Observational Studies in Epidemiology [40]. The data were collected between March and April 2022. Written informed consent forms were obtained from all the participants before their inclusion. All the

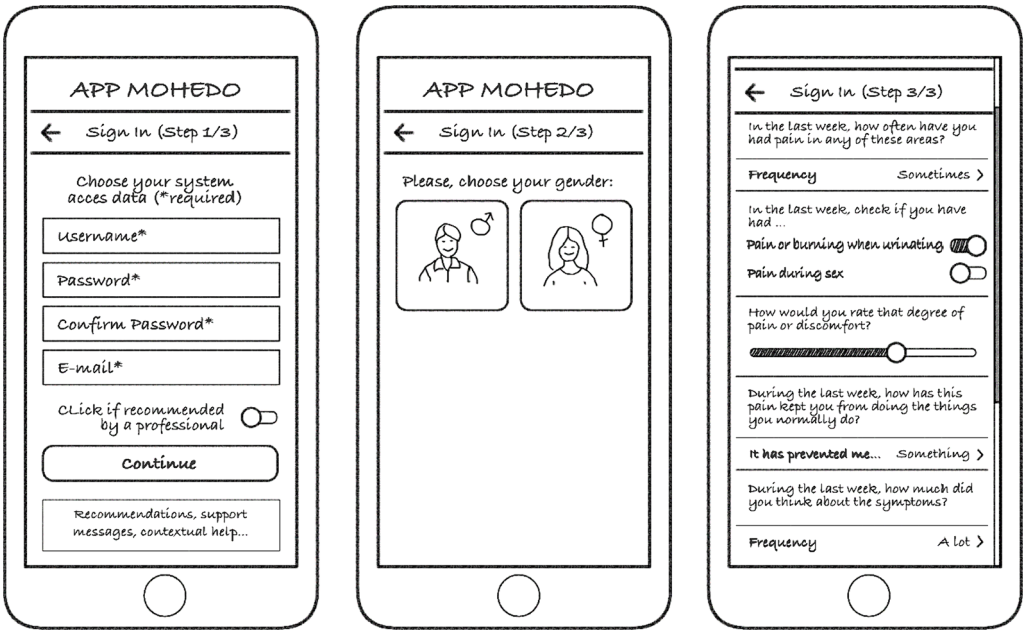

Fig. 5. Some *wireframes* resulting from the phase of low-fi prototyping.

participants received an explanation of the study procedures, which were planned according to the ethical standards of the Declaration of Helsinki. Ethics approval was received from the Bioethics Committee of the Medical University of Málaga (17–2022-H).

2.2.1. Participants

A total of 132 volunteer university students from Engineering, Education, Psychology, and Industrial Organization Engineering were recruited through their professors by non-probabilistic convenience sampling.

The inclusion criteria were as follows: (a) Spanish-speaking men and women, (b) of legal age. The exclusion criteria were: (a) being diagnosed with dyslexia and/or chronic pain (CP), (b) having previously undergone MI training, (c) studying a degree related to Health Sciences and (d) completing the task unsuccessfully (exceeding the time, leaving the task incomplete, etc.).

2.2.2. Outcome measures

Left/Right judgment task (LRJT) Accuracy: The number of correct responses was expressed as a percentage of the total number of pictures displayed.

Response time (RT): The mean RT for responses was called response time, and it was expressed in minutes and seconds.

All variables were collected through an electronic link.

2.2.3. Procedure

Control task: left/right judgements of photographs of the abdomino-pelvi-perineal area.

The participants undertook the left/right abdomino-pelvi-perineal area judgment task using the established protocol. Five hundred and fifty photographs of the right and left side of the body, in various positions and divided by sexes, were employed in random order using one part of the App-Mohedo® software. A total of 40 images were shown to each participant. The participants responded by pressing one button on their mobile if the photograph showed a left abdomino-pelvi-perineal area, and a different button if it showed a right abdomino-pelvi-perineal area. Emphasis was placed on the speed and accuracy of the responses. That is, the participants were instructed to make accurate responses as quickly as possible. A single trial constituted the task.

2.2.4. Protocol

A member of the research team was present in the class; the participants were asked to make themselves comfortable to take the test. Then, they were given the electronic link, which gave them access to the completion of the basic information, as well as to the realization of the visual iMI test. Prior to the imagery test, they visualized a short explanatory video about the task. Once this video was visualized, the researcher asked the participants if they were ready and requested them to place their thumbs on the appropriate response keys for left and right answers. Then, the participants performed the left/right-abdomino-pelvi-perineal area judgement task. Until the end of the task, the researcher accompanied the participants to ensure that they did not receive any help, got distracted or performed the task the wrong way.

2.2.5. Data analysis

All statistical analyses were performed using The Jamovi (2021) [41] and R Core Team (2022) [42]. Background variables are presented as means and standard deviations (SD), or as frequencies and percentages. We used *Student's T-tests* to analyze differences according to sex, and *Pearson's linear correlation* to analyze the linear association between the percentage of correct answers and the response time. The results of the study for the classification of the images are detailed and analyzed in the following section.

2.3. The final implementation of AppMohedo (phase 5)

Considering the results of the evaluations conducted in the previous 2 phases, and after ordering the content of the therapy in difficulty levels, we developed the final app and translated it from Spanish to 4 languages (English, French, Italian and German).

The *frontend* was programmed using also IONIC, and the *backend* or engine of the application was programmed using Laravel, complemented with Angular JS (JavaScript).

Once deployed and put in production in an Internet server, the application can be used as an app for Smartphone and Tablet (through markets), and as a website.

3. Results

3.1. App prototyping (phases 1 to 3)

As a result of the continuous prototyping and evaluation process conducted in the first 2 phases and, especially, in phase 3 (HiFi software prototype user testing), and considering the problems detected and the suggestions of the users, it was necessary to make the changes that are summarized in Table 1.

3.2. App content development: Images classification results (phase 4)

Fig. 6 shows the flowchart of the sample of participants (initial sample n = 132 individuals; n final = 70 individuals).

Table 2 presents the demographic characteristics of the participants who were ultimately included in the study. There were no significant differences between groups as a function of age.

After grouping the data by images and limiting them to 10 s (which we estimated to be a reasonable *response time* to include them in the study), the results are distributed as is shown in Fig. 7, i.e., most of the images present a *mean RT* of 1–2.5 s.

Firstly, we analyzed the behavior of the data considering the answers of the participants. When the data were clustered at the individual level, no significant relationship was found ($r = 0.03$) between the response time and the number of correct answers.

Secondly, we analyzed the data considering the results of *RT* and *Accuracy* for each image (disregarding the individuals). It was observed that those images with which the participants took less time to respond had a greater percentage of correct answers ($r = -0.23$, $p < 0.001$), as can be observed in Fig. 8.

For the final classification of the 550 images, *LRJT-Accuracy* and *mean-RT* were taken into account. Table 3 shows the results of the variable *LRJT-Accuracy* for all participants, as well as *LRJT-Accuracy* for each sex. Table 4 shows the results of the variable *mean-RT* (measured in seconds), both for the total sample and for each sex.

Setting levels

As was indicated above, the two analyzed variables, i.e., (1) *LRJT-Accuracy* and (2) *mean-RT*, of each image are the ones that were considered to categorize the images by difficulty levels. Therefore, *LRJT-Accuracy* was established as the first criterion, and *mean-RT* was established as the second criterion. Thus, the images with 100 % *LRJT-Accuracy* and a *mean-RT* of 0–2.5 s were assigned to level 1. The images with 75–99 % *LRJT-Accuracy* and a *mean-RT* of 2.5–5 were assigned to level 2. Lastly, the images with 50–75 % *LRJT-Accuracy* and a *mean-RT* of over 5 s were assigned to level 3 (Fig. 9).

Regarding the characteristics of the images in each level, there is a common characteristic in all levels: the number of black-white images in each level is similar, which indicates that color does not hinder the identification of the image.

However, the position of the image seems to have an impact on the results: in level 1, most of the images belong to the posterior part of the body; level 2 is predominated by lateral images of the body; and, in level 3, most images show the anterior part of the body and/or genitalia (Fig. 10).

Therefore, we can conclude that the direct relationship between the images of the same level is based on body position and the presence or absence of genitalia, regardless of whether the image is colored or black and white.

3.3. The final implementation of AppMohedo (phase 5)

Once the last improvements were applied, as a result of phases 4 and 5, we will specify the final result of the development of the app, as well as the options it offers and how to use it.

Table 1
Problems detected and aspects to improve as a result of the evaluation of the interface performed in phases 2 and 3.

Phase	Where is the change applied?	Description
Phase 2.3a: *LowFi Heuristic evaluation*	General	Always place the "back to main menu" (or previous screen) icon at the upper left corner, and the "exit" icon at the upper right corner (it is adopted by convention, and by coherence and consistency with the interface).
	General	Modify the size of some controls, and further separate them from each other and from the borders of the screen.
	Results of one session	Initially, the sessions were labelled as "today@hhmm". Now we propose using a more friendly and natural language (for instance: Today, at hh: mm). The same goes for the days (we change from 20/10 to 20oct).
	Theoretical fundamentals of the app:	Include a FAQ and help section.
Phase 2.3b: *LowFi User Testing*	Theoretical fundamentals of the app	Rename this section.
	Graph of results	Change the vertical bar graph (which was initially used to show the results of correct answers) for another graph of 3 superimposed lines (one for correct answers, another one for time, and the third one for the degree of pain).
Phase 3: *HiFi User Testing*	Indicator of the degree of pain	Modify the spinner (which is used to indicate the current degree of pain at the beginning of each session) so that it does not have graded scales or words that may posed doubts (only the bar, without values)
	Theoretical fundamentals of the app	Include an entry in the FAQ section about what the user will obtain at the end of the session (information and encouragement to go on, since the aim is not to finish as soon as possible, but to judge laterality the best they can) Include an explanatory video showing the use of the app (before, it was only available once the "begin session" option was selected). In the tests, different users stated that, after watching the video (in some cases they went straight to it), they had a clearer idea of what they were going to do. Incorporate a message related to the essence of the exercise: the good evaluation of laterality versus speed.
	Table of results of one session	Highlight in red the incorrect answers.
	Graph of results	Although the vertical bar graph (initially used to show the results) had been replaced with another graph with 3 lines, it is now necessary to offer the possibility of hiding/showing each of them individually. Include a very clear caption describing the previous function. Refine the colors of the three lines of the graph, increasing their contrast, and giving them the names of the parameters they represent (correct answers, time and pain).

- After installing the app, the first step for all users is to register, which is completed by completing the following 3 steps (Fig. 11):

1. *Specification of user and password*. If the user-patient is referred to the use of the app by a healthcare professional (who will previously have a code assigned), he/she must indicate this in the corresponding box

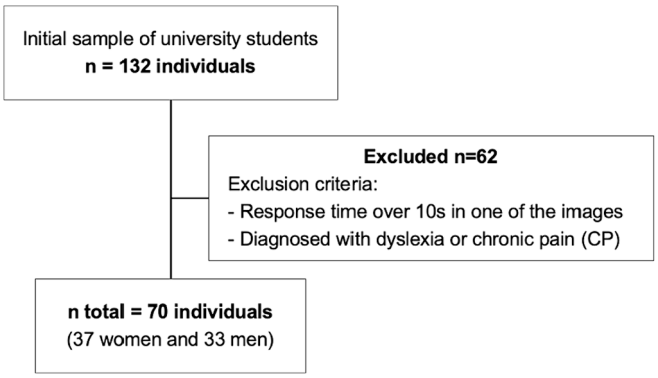

Fig. 6. Flowchart of the sample.

Table 2
Descriptive statistics of demographic variables.

	Mean (SD)	Range	p value
Age (n = 70)	22.4 ± 4.3	18.3 – 46.9	0.579[a]
Age by sex			
Woman (n = 37)	22.7 ± 5.6	18.3 – 46.9	
Man (n = 33)	22.1 ± 2	18.4 – 26.5	
Degree	**Percentage**		
Degree of Industrial Technology Engineering	15.71 %		
Psychology	21.43 %		
Primary Education	35.71 %		
Industrial Organization Engineering	27.14 %		

[a] Linear Model ANOVA

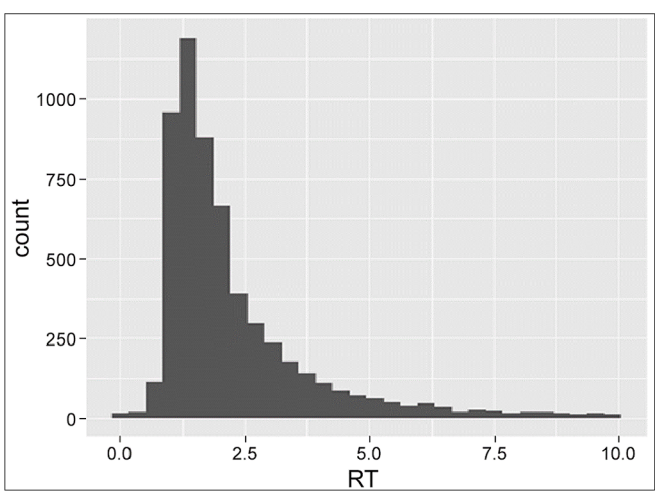

Fig. 7. By relating RT to the number of visualizations of the images, and limiting the data to 10 s, a more homogeneous distribution of the data is observed.

of the registration if he/she allows such professional to access his/her information and evolution.

2. *User sex selection*. This will influence the obtained data and the subsequent therapy, as the latter will be adapted to the sex selected.
3. *Personal-clinical profile*: in addition to age, weight, and height, it is important to introduce questions that help to discriminate whether the user is a CPP patient or not, since, apart from a professional who has made the clinical diagnosis, the app can be accessed by other users. In this regard, we included questions from the validated questionnaire CPP-Mohedo [43]. Similarly, and in order to objectify the efficacy of the therapy, a visual analogical scale was also included, through which the user, via slider, must indicate her/his level of pain in the last week. Both questions allow discriminating whether the user is or is not a CPP patient, thus concluding the "registration" process.

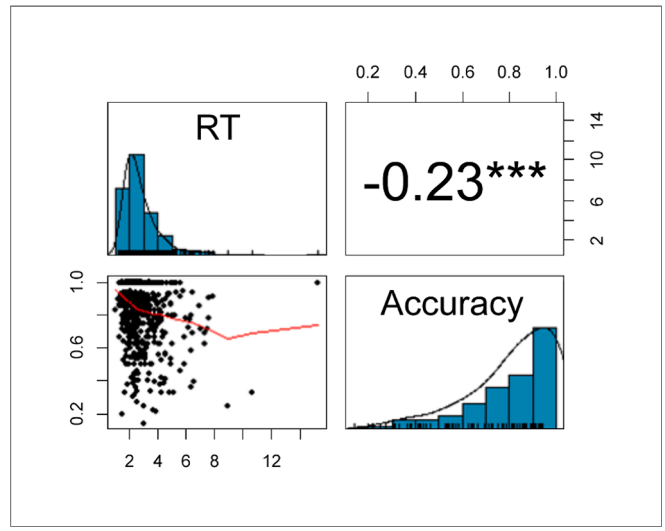

Fig. 8. Results grouped by images. RT is positively related to the percentage of correct answers (Accuracy). Moreover, some data generate heterogeneity.

Table 3
Statistics of the variable *percentage of correct answers*.

	Mean (SD)	Range	p value
Percentage of correct answers (n = 70)	82.9 ± 18.1	10.0—100.00	0.091[a]
Percentage of correct answers by sex			
Woman (n = 37)	79.4 ± 16.6	47.5–100.0	
Man (n = 33)	86.7 ± 19.2	10.0– 100.0	

[a] Linear Model ANOVA.

Table 4
Statistics of the variable *mean Response Time* (measured in seconds).

	Mean (SD)	Range	p value
Mean response time (n = 70)	2.0 ± 0.5	1.3 – 3.3	0.463[a]
Mean response time by sex			
Woman (n = 37)	2.0 ± 0.6	1.3 – 3.3	
Man (n = 33)	1.9 ± 0.4	1.3– 2.8	

[a] Linear Model ANOVA.

Once registered, the user can use the app, with the possibility of choosing one of the following options: (a) modifying his/her registration data, (b) obtaining information about the scientific foundation of the iMI therapy, (c) performing a therapy session, or (d) checking the results of previous therapy sessions. These options are always available in the menu of the app. Next, we describe options (c) and (d).

- When the user is registered, he/she can *initiate a therapy session* of image laterality discrimination, by activating the "start" command in the main menu. From this moment, he/she will receive a total of 15 random images from the corresponding difficulty level and will have to classify them as "right" or "left".

  After completing the task, the user will receive a message indicating that the session is over, along with a report of her/his results, and she/he will not be allowed to perform another session in the next 4 h. The transition from one difficulty level to the other was

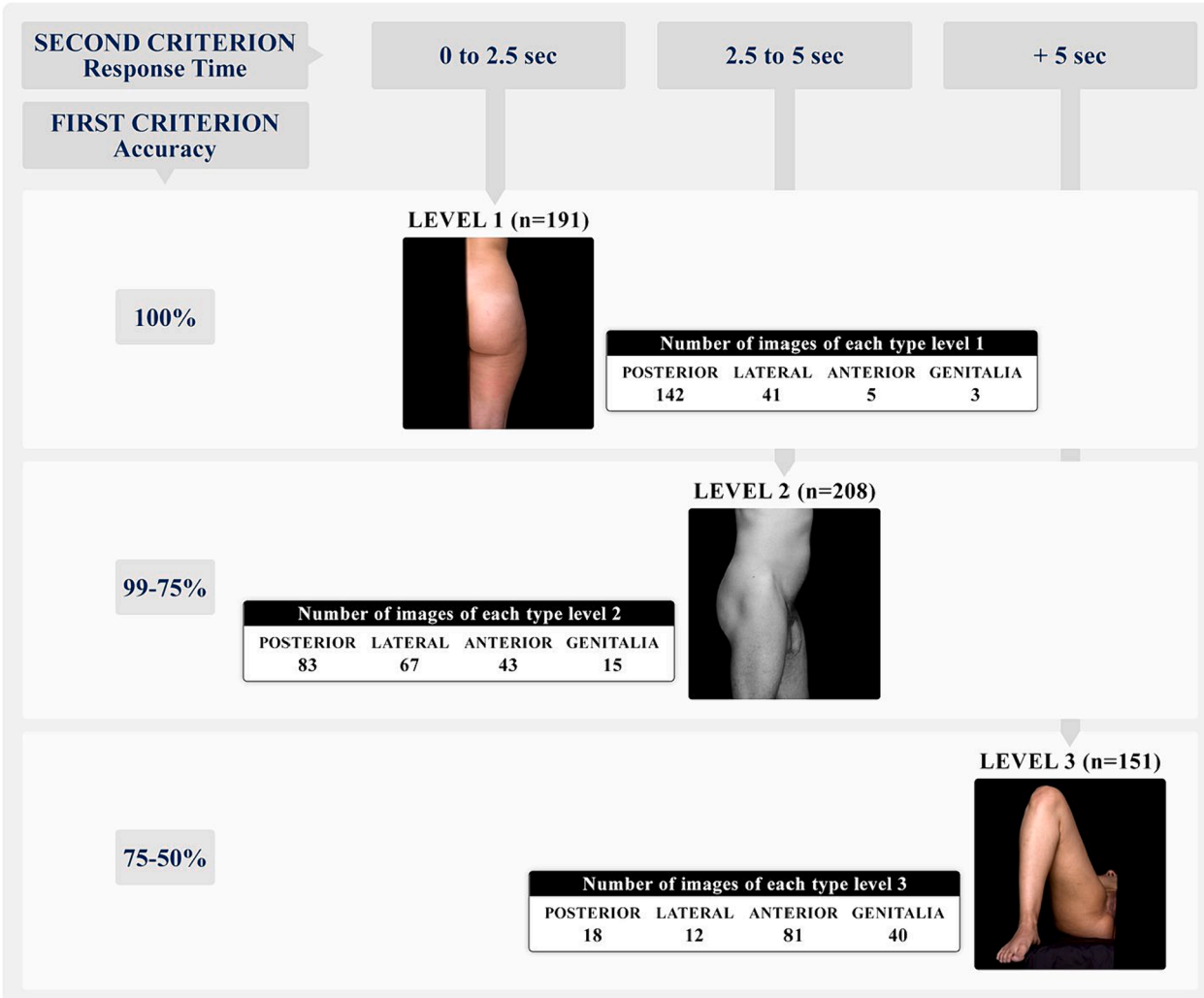

Fig. 9. Classification of images by difficulty level according to *accuracy* and *response time*.

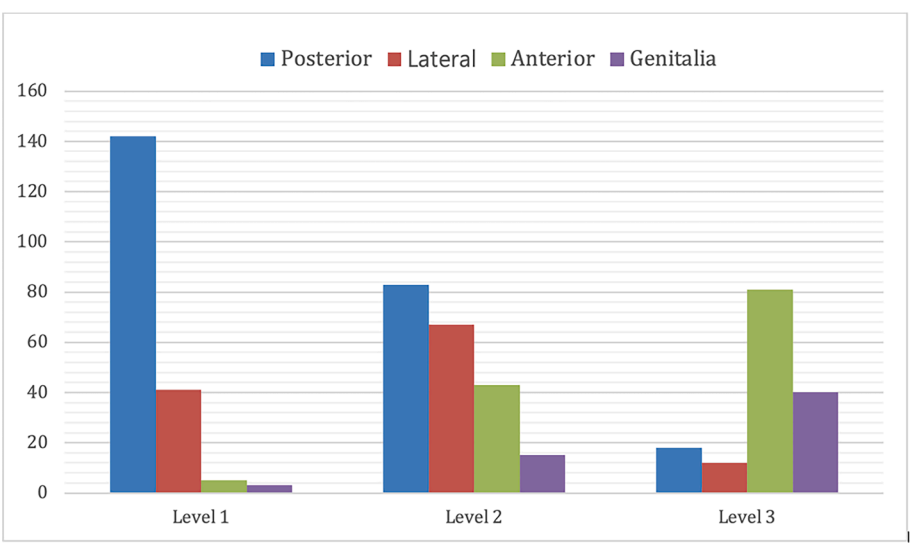

Fig. 10. Distribution of each type of image by levels.

programmed to occur when the user completes 3 sessions with over 80 % accuracy.

- The user's need for *feedback*, which is important for the appropriation of the app (i.e., making it one's own) and, therefore, for the reliability of its correct use, is materialized in the system of levels

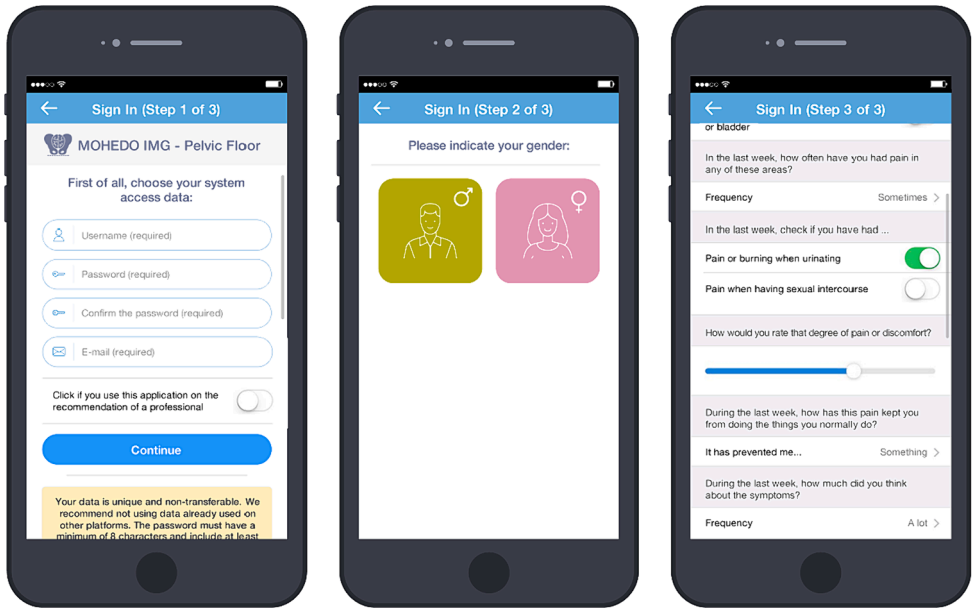

Fig. 11. Screens of user registration in App-Mohedo®.

that are passed (advance) and in the table of results shown (Fig. 12). This information is expanded, being also offered for other time ranges (day, week, or month) and graphically, using a format of lines that represent the values (as %) that correspond to the number of correct answers, time used, and the level of pain stated (Fig. 12).

4. Discussion

The use of GMI and, specifically, LRJT proved to be a reliable, non-intrusive method with no adverse effects, which make it an evaluation technique to complement the therapeutic treatment of any chronic pain, including CPP.

This is the first work to describe the development of an app to

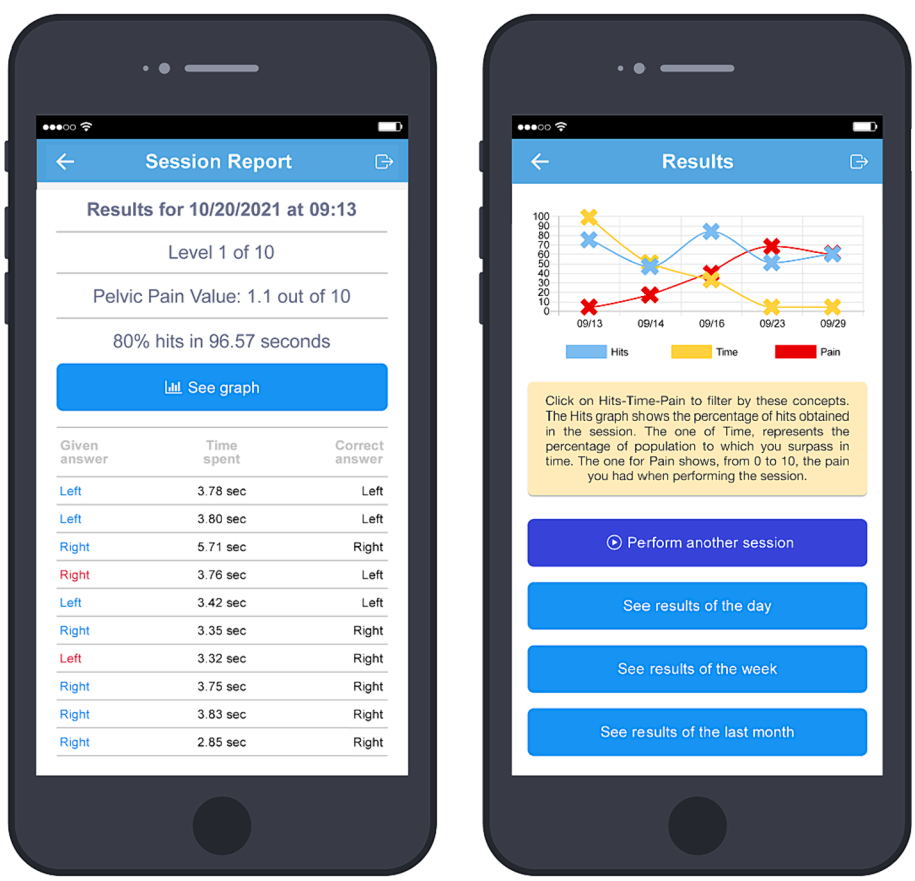

Fig. 12. Results screens: (a) after completing a therapy session and (b) after selecting the visualization of the graph that corresponds to the last month.

complement the management of people with chronic pelvic pain. Specifically, App-Mohedo® is a multi-platform tool designed for mobile devices that, after organizing and classifying its images in difficulty levels, allows evaluating, training, and improving the capacity of the individual to assess whether the observed image of the abdomino-pelvi-perineal area belongs to the left or right side of the body. During this task, both accuracy (number of correct answers) and RT (response time) are analyzed, since these parameters are correlated with pain and potentially altered in pain conditions such as CPP.

4.1. Concerning the design and development of the app

The development of this tool, following a collaborative, user-centered methodology, was aimed at meeting quick prototyping and evaluation objectives, in order to obtain, from the very beginning, feedback from the users, who also participated throughout the entire design process.

An easy-to-use app was obtained, which can be adapted to different devices, with a friendly and clear design, based on light colors and clear fonts, prioritizing, and optimizing the image visualization space. The elements of the user interface (buttons, sliders, etc.) were designed with standard format and comfortable size for all types of users.

It is important to point out that the user is actively always helped, with contextual information and tips. Moreover, for the discrimination task, an explanatory video is available for visualization.

One of the most relevant aspects of the tests conducted with the users is that an irregular understanding of the multivalued bar graphs (included in the first prototypes) was detected, thus we decided to switch to the superimposed lines format, with one line per datum, which can be shown/hidden by pressing some controls. This enables individual reading and its superimposed visualization, at will, and it turned out to be more useful and clearer for the users (Fig. 12).

Furthermore, multiplatform development tools were used, where codification is performed only once for the different types of mobile devices. This allows making quick changes in the design and behavior of the application. This tool does not require intense data processing, but rather a clean and understandable interface. Platform native code development would have been a costly and unnecessary delay in this work.

4.2. Concerning the content: The images and their classification in difficulty levels

A small number of the images generated and analyzed did not meet the two criteria of a certain level; that is, by LFJT Accuracy they belong to one level, and by mean RT they belong to the other. After conducting a subsequent study of the characteristics of the images of each level, the researchers decided, after some consensual rounds and based on the peculiar characteristics of the image (position of the subject, rotational component, presence or absence of genitalia, etc.) their ultimate allocation to their corresponding level. The future analysis of such images with the tools offered by artificial intelligence may shed light on this matter, considering and creating more objective variables for this purpose.

The information obtained from the observation of the images of each level indicates the difficulty of recognizing the frontal pelvic zone, especially the genital area, in both healthy men and women, which we discuss below.

Until recently, there has been a lack of research on the representation of the genitalia in the cerebral cortex. Since the publication of the well-known somato sensory homunculus (1950), which represents the functional somatotopic organization of the primary sensory cortex, numerous studies have added new information to what is known about the somatosensory cortical representation of the human body. The study conducted by Cazala F. in 2015 tentatively suggests that there are two distinct representations of genital sensations in primary somatosensory cortex (SI)[44].

In addition, the cortical representation of male and female genitals, unlike that of the rest of the body, undergoes late expansion during puberty and is modulated by sexual experience [45]. Genital self-image is an emerging aspect of body image relevant to sexual functioning and sexual satisfaction [46]. These contributions to the field of body image and sexual experience are important, since it is demonstrated that genital self-image, over and above general feelings about one's body, can influence sexual satisfaction and the experience of sexual problems and, therefore, result in greater knowledge about the genital area [46].

Alternatively, negative social attitudes towards adolescent sexuality suggest that specific dimensions of sexual self-concept could decline throughout adolescence, or in earlier stages and increase later. These findings could indicate that an accumulation of experiences generally bolsters confidence and reduces negativity about sexual matters, or that young women without intercourse experience begin to view sex in more positive terms as they gain confidence in pre-intercourse activities or anticipate their first sexual encounter. However, it should be noted that both women and men report negative genital self-image [45].

On the other hand, it is known that positive genital self-image is positively related to sexual desire and positive body perception.

In addition to the sensitive part that comprises the genital area, it is known that there is poor proprioception of the pelvic muscles, which can be attributed to the lack of visual stimuli and the scarce joint movement during contraction. This proprioceptive deficit is combined with a lack of knowledge about one's own pelvic and genital area [47].

It is clear that the LD task of GMI with the images presented to our sample required the activation of brain areas, although we cannot confirm the influence of a proprioceptive deficit, poor self-image or bad sexual experiences. We can only assert that our participants found it more difficult to plan, adjust, automatize, and voluntarily execute postures and/or movements shown in the images of genitalia. It would be interesting for future studies to gather these variables and estimate their relationship with our results.

Although the majority of studies that use LRJT have not controlled for iMI ability and cognitive factors such as concentration/attention [46], the present results suggest that such control is necessary when attempting to understand the different processes involved in LRJT performance. Therefore, this study excluded those individuals who took over 10 s to identify an image, considering it a lack of concentration in the assigned task.

4.3. Conclusion

This paper describes the iterative and user-centered process applied to the development of the App-Mohedo®, which was created to be used as a complementary therapeutic tool in the management of CPP patients, through iMI and laterality judgement training. We also intend our work to serve as an example, model or guide when applying the MPIu + a user centered methodology to the development of new apps in the field of health (and even in other fields). Our work also includes the generation of the main content of the app, 550 pelvic floor images, as well as the subsequent empirical study that allowed us to classify them into 3 difficulty levels, which is fundamental to be able to organize and plan the patients' therapy sessions with the app properly.

The app has the potential to both reinforce information provided during a rehabilitation intervention and provide complementary rehabilitation strategies to users who can engage in self-management independently. It may strengthen the patient's relationship with the therapist, increase engagement, and enable the patient to proactively address concerns related to their rehabilitation.

The next step is to test the app as a therapeutic tool (by means of a Randomized Clinical Trial) to verify whether training with such images really helps to modulate pain intensity and to improve the quality of life of these patients, which is the end goal that motivates the creation and development of this app.

Summary table.
What was already known on the topic?

- Chronic Pelvic Pain (CPP) is among the most prevalent and costly healthcare problems.
- Graded motor imagery (GMI) is a therapeutic tool that has been successfully used to improve pain in several chronic conditions, especially using Implicit Motor Imagery (iMI) and Left Right Judgement Task (LRJT).
- To date, only one application using iMI with LRJT has been developed to improve the treatment of other chronic pain conditions (in hands, feet, back, neck, shoulders and knees), but not for the pelvic floor.
- To date, there is no app that uses and applies iMI with LRJT to improve the CPP.

What this study added to our knowledge?

- App-Mohedo® is the first multi-platform, multi-language, and easy-to-use mobile application that, through iMI with LRJT, and with an adequate bank of images classified into three levels of difficulty, can be used as a complementary therapeutic tool in the treatment of patients with CPP.
- The process follows for the development of this App can also serve as an example, model or guide when applying a user-centered methodology, as MPIu + a, to the development of other apps, especially in the field of health.

CRediT authorship contribution statement

Esther Díaz-Mohedo: Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Validation, Writing – original draft, Writing – review & editing. **Antonio L. Carrillo-León:** Conceptualization, Formal analysis, Investigation, Methodology, Software, Supervision, Writing – original draft, Writing – review & editing. **Andrés Calvache-Mateo:** Conceptualization, Investigation, Validation, Writing – review & editing. **Magdalena Ptak:** Conceptualization, Investigation, Validation, Writing – review & editing. **Natalia Romero-Franco:** Conceptualization, Investigation, Validation, Writing – review & editing. **Juan Carlos-Fernández:** Conceptualization, Investigation, Validation, Writing – review & editing.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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